DEC 15 1936

Engineering News-Record

McGraw-Hill Publishing Company, Inc. December 10, 1936 Twenty-five Cents. Five Dollars per Year

Rodriguez Dam in Mexico, most recent dam of the slab and buttress type and the highest to be built.

IN THIS ISSUE: The Climax of an Era of Dam Building . . . Water Conservation and Flood Control by the TVA . . . Express Highways . . . Determining Beam Deflections . . . Novel Features of Englis

UNIV OF MICHIGAN
GENERAL LIBRARY
ANN ARBOR MICH
J-C

LOADING AND DUMPING IN MUD AND DUST

The Tygart Dam project called for a new railroad grade near Grafton, W. Va. The problem was to get dependable equipment that could work through deep mud in the rainy season and almost unbearable dust in the dry season.

"Caterpillar" Diesel Tractors were chosen to haul the big track-type wagons—and kept the job on schedule. The photographs show one of these units loading from a "Caterpillar" Diesel-powered shovel and dumping on the fill.

Get the figures on this low-cost, record-making hauling unit. A "Caterpillar" dealer can give them to you—and the facts on "Caterpillar's" world-famous service facilities. Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

CATERPILLAR

REG U. S PAT. OFF.

Diesel

Off the Record

THIS page is off the record; it is distinctly personal. Flinging aside the constraint of the third person imposed by custom upon the non-editorial commentator, I want to record a word of thanks to the many readers who, from time to time, take the trouble to write me about what appears on this page.

The "fan mail," as such correspondence is irreverently dubbed by the office staff, is one of the major satisfactions derived from the conduct of this page. To those who may commend what is said here, I naturally am grateful for their encouragement. To those who volunteer constructive suggestion and comment, I am indebted for the information and stimulus they bring. But toward those who take issue with the views of this page, I feel a very special sense of obligation.

Now and then one of these takes a rather vicious crack at the morals and motives of anyone who could entertain the opinions here advanced; although such writers usually shed but little light on the subject, even they are useful thermometers to reveal the heat that may be generating with respect to it.

More often I am chastised, more in sorrow than in anger, by one who suggests another viewpoint or volunteers some special information to justify his dissent. Such, indeed, are friends, seeking to set right one who may seem to err through a failure of performance rather than of purpose.

Most often, needful admonition is even more tenderly couched in phrases such as "every now and then one of your articles peeves me, but . . ." or, subtly, "*most* of your articles are good." These are the very considerate folk whose generosity grants full credit for what may be good and whose charity withholds comment on what is not.

TO all these my thanks are due. Their commendation and criticism provide the light and shade that throw into relief those ideas and viewpoints that constitute the prevailing sentiment of a profession or an industry.

We are living through vibrant times; we are working in a field of far-flung and diversified endeavor. To no man is vouchsafed a corner on the vision, the knowledge or the wisdom to appraise accurately and interpret justly the significance of what is happening all about us.

All we can do is try our best to be fair and honest—try to see the facts clearly, to weigh them dispassionately, to interpret them with due regard for the general welfare and to champion our conclusions temperately and with due respect for those who disagree.

As a technical man, every engineer is trained in a field where fact and reason eventually must rule; his mathematics and mechanics know neither emotion nor prejudice. Here, if anywhere, we should find men predisposed to appraise rationally even the human aspects of their problems. This does not imply that they will or can succeed fully in that praiseworthy effort for, after all, they still are human.

BUT in the maelstrom of self-interest, prejudice, partisanship and emotional propaganda of man against man and class against class in which we all are caught and carried along, we owe it to ourselves, to the profession or the industry in which we work and to the community of which we are a part, to do our best to apply to the discussion of our common concerns the reasonable temper that is enjoined upon us by our calling.

In that spirit this page is written each week. When it falls short, it is a failure of capacity rather than of intent. And in that spirit, I step out of my part this week to record my gratitude to all those who, through their comment and admonition, help to keep my feet on the ground and my head on the level.

Willard Chevalier

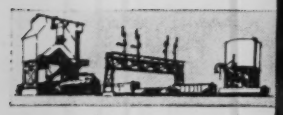
ENGINEERING NEWS-RECORD Published every Thursday. Vol. 117, No. 24. Price 25c per copy. Subscription, domestic, Canada, Mexico, Central and South American countries, $5 per year. All other countries, $9 a year or 36 shillings. Entered as second-class matter October 29, 1936 at the Post Office at Albany, N. Y., under the act of March 3, 1879. Printed in U. S. A. Cable address "McGrawhill New York." Member A. B. P. Member A.B.C.

Copyright 1936 by McGRAW-HILL PUBLISHING COMPANY, INC.

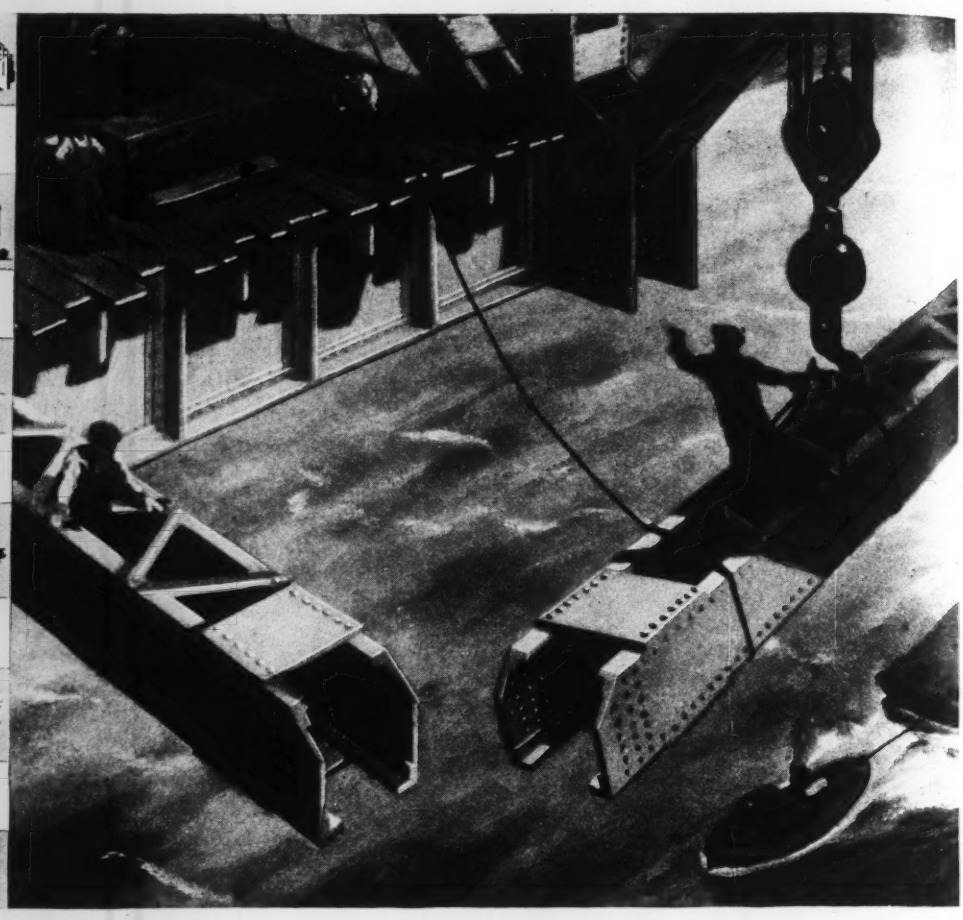
Editorial and Executive Offices: 330 West 42d St., New York. Publication Office: 99-129 N. Broadway, Albany, N. Y. Branch Offices: 520 N. Michigan Ave., Chicago; 883 Mission St., San Francisco; Aldwych House, London, W. C., 2, England; Washington; Philadelphia; Cleveland; Detroit; St. Louis; Boston; Atlanta, Ga.

JAMES H. McGRAW, JR., Chairman — MALCOLM MUIR, President — JAMES H. McGRAW, Honorary Chairman
WILLARD CHEVALIER, Vice President — B. R. PUTNAM, Treasurer — D. C. McGRAW, Secretary

Table of Contents—See page 17



INLAND STEEL



Miracle Building with Inland Structural Steel

THE MILL and THE MEN . . . *that's* INLAND

It is perhaps quite impossible to impart an intimate idea of how Inland mills and men seem to blend into one great instrument of service to American Industry. • A personally conducted trip through one of the Inland Plants would help toward such an understanding. • You are cordially invited to visit whenever it may be convenient for you.

Principal Products

SHEETS STRIP TIN PLATE
PLATES STRUCTURALS PILING
RAILS TRACK ACCESSORIES
BARS BILLETS

Many present day structures are literally miracles of building . . . and each year brings new wonders, new revelations of the ability and genius of architects, engineers and contractors. Tunneling deeper into the earth, building higher into the sky, and spanning vast stretches of water—these men use only materials on which they can depend without question. We are, therefore, particularly pleased that Inland Products are so extensively specified.

Thousands of tons of Inland structural steel go into bridges, buildings, dams, seawalls and other structures every year. • But furnishing uniformly strong, dependable steel is only a part of the picture, for Inland Engineers work closely with designers, fabricators and erectors, from foundation to flag pole, making practical suggestions, deliveries as needed, and giving that close personal attention to every detail that saves time and means so much to successful building.

INLAND STEEL CO.

General Offices: 38 South Dearborn Street, Chicago, Illinois

ENGINEERING NEWS-RECORD

McGraw-Hill Publishing Co., Inc.

Editorial and Executive Offices: 330 West 42d St., New York Publishing Office: 99-129 No. Broadway, Albany, N. Y.

Editorial Staff
V. T. Boughton
W. G. Bowman

Chicago
W. W. De Berard

F. E. Schmitt, *Editor* Willard Chevalier, *Vice-President*

Editorial Staff
C. S. Hill
H. W. Richardson
E. J. Cleary

San Francisco
N. A. Bowers

Volume 117 Number 24 Copyright 1936

DECEMBER 10, 1936

Dam Building Reaches a Climax ..... *R. A. Sutherland* 807

How Shall Height of Dams be Measured? 816

Metered Parking Systems 817

Novel Features of English Sewage Treatment
Willem Rudolfs 819

The Tennessee Valley Experiment—II
Water Conservation and Flood Control 823

Determining Beam Deflections Without Integrating
Odd Albert 828

Current Highway Problems—XI
Express Highways ..... *J. S. Worley* 830

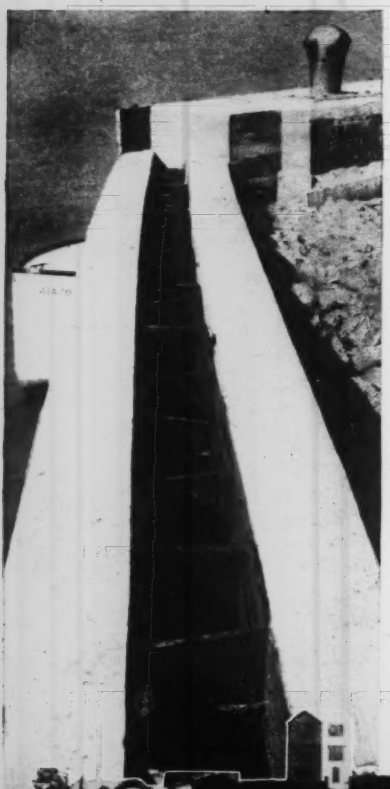
Control of Rock Dust in Construction—III
Silicosis Legislation 832

Editorials 836
Current News 838
Unit Prices 844

Road Design—PRESENT DESIGN PRACTICES of highway departments are to be reviewed and appraised in the issue of January 7, the Annual Highway Number. The articles are by recognized authorities in the several fields covered.

Building for the Future

WITH MZ-32

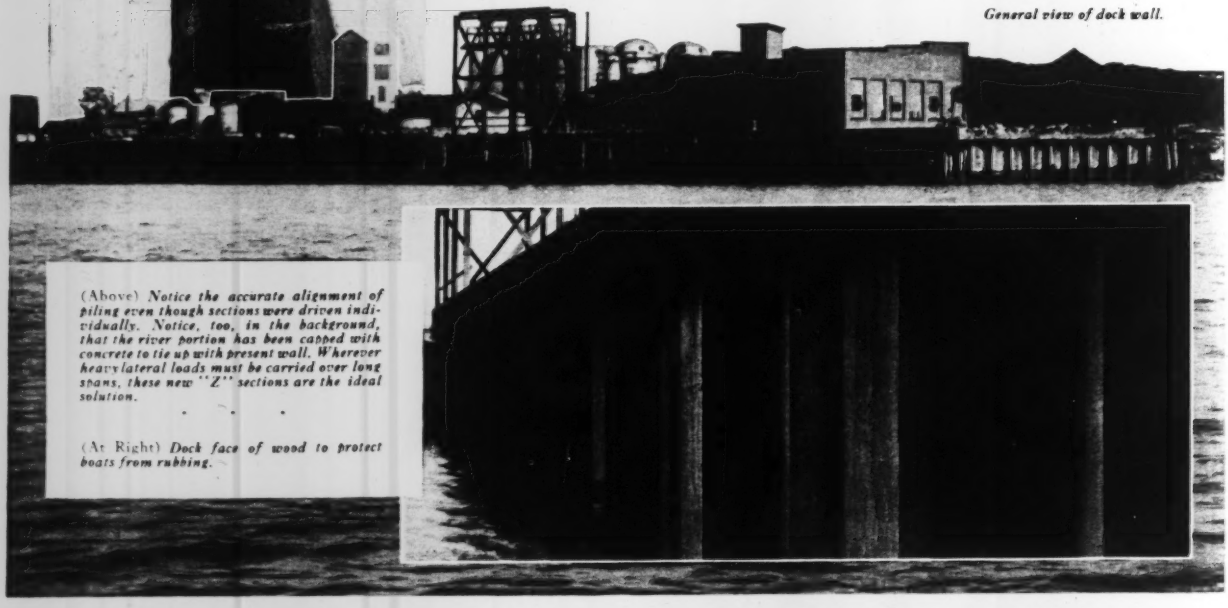


HERE on the Maumee River, Toledo, Ohio, engineers and contractors were faced with the problem of building a dock wall that will meet both today's and tomorrow's needs. Designed to be used as an unloading dock for tankers of the Gulf Refining Company, this wall had to be constructed to carry heavy surcharge loads—had to be built to provide for deeper drafts of water for future lake shipments.

To meet this situation the L. A. Wells Construction Company of Cleveland used MZ-32 in 45′ 5″ lengths—150 tons in all. Weighing only 32 pounds per square foot of wall, 56 pounds per lineal foot of pile, yet developing a section modulus per lineal foot of wall of 38.3 inches³, MZ-32 was the ideal solution for present and future requirements.

The first "Z" Piling sections to be rolled in this country, both MZ-38 and MZ-32 insure smooth driving, easy penetration, uniformly accurate alignment of piling. Having the highest beam strength compared to weight ever developed, these new sections make possible new economies in the construction of all marine structures—permit designs not only to meet present needs, but future demands as well. A 16-page addition to our piling catalog tells you why. Write for it.

General view of dock wall.



(Above) *Notice the accurate alignment of piling even though sections were driven individually. Notice, too, in the background, that the river portion has been capped with concrete to tie up with present wall. Wherever heavy lateral loads must be carried over long spans, these new "Z" sections are the ideal solution.*

(At Right) *Dock face of wood to protect boats from rubbing.*

U·S·S STEEL SHEET PILING

CARNEGIE-ILLINOIS STEEL CORPORATION

Pittsburgh *Chicago*

Columbia Steel Company, San Francisco, *Pacific Coast Distributors*

United States Steel Products Company, New York, *Export Distributors*

UNITED STATES STEEL

ENGINEERING NEWS-RECORD

December 10, 1936

COOLIDGE DAM in Arizona, a multiple-dome structure, is notable as a bold departure from traditional design practice.

Dam Building Reaches a Climax

Present decade marked by the completion of dams of unprecedented heights and ever increasing volume in the major classification of gravity section, arch, buttress, and earth and rockfill

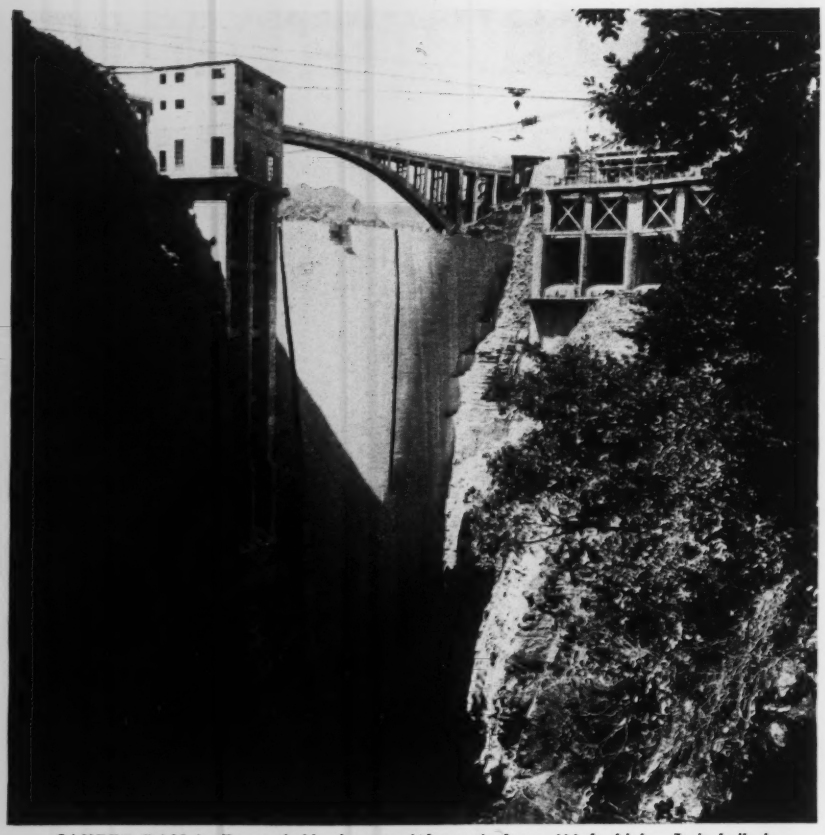
By Robert A. Sutherland

Central Nebraska Public Power and Irrigation District, Hastings, Neb.

COMPLETION of Boulder Dam with its unprecedented height of 727 ft., and a volume of 3,250,000 cu. yd., and the approaching completion of Fort Peck Dam and the base section of Grand Coulee Dam cannot but raise the interesting question of whether the present decade will not in the future be looked upon as the climax of an era of dam building that began near the middle of the nineteenth century. When the nineteenth century opened, the world was in what may be called the canal-building era. But the successful development of the steam locomotive in the 1820's soon resulted in a decline of canal building and inaugurated an era of railroad building. That period had passed its peak by the opening of the twentieth century at about the time that dam building began to show a rapid increase in height of structure whose construction was undertaken.

The causes that brought about the present era of dam building are more varied than those that led to the canal and railroad-building eras, and they varied from one country to another. Speaking generally, irrigation and the provisions of water supply and water power for growing industrial centers were predominant reasons, with flood control becoming an important factor in later years. Now that we have reached what, from our limited view, appears to be the climax, or at least a definite peak in the era of dam building, it is of interest to review that period setting down the principal characteristics of the major structures and outlining some of the developments that have marked its various stages.

In this review, only dams over 100 ft. high are considered, for it is obviously impossible to note all, or even any appreciable precentage of dams of lower heights, if for no other reason than that many such dams of lower heights have received little or no recognition in the pages of technical literature. There are probably well over a thousand dams from 50 to 100 ft. high, and tens of thousands of dams of less height. It is stated that in one section of India alone there are 43,000 earth dams or tanks in use, mostly of small height, but some of them over 50 ft. high. It must be remembered, however, that many dams less than 100 ft. in height, although not mentioned here, are exceedingly important structures, both in their beneficial results and in the amount of work involved in their construction, but the problems connected with such structures generally are those of foundation methods rather than problems connected with the dam itself. Dams of greater height offer increasing problems, both of design and technique of construction, and development of the site they occupy, in many cases, had to await improvements in methods and materials before becoming feasible.



SAUTET DAM in France holds the record for arch dams, 414 ft. high. It is built in a narrow gorge that lends itself admirably to this type of structure

The gravity dam of a century ago was of unscientific section and made of materials that would not now be considered first class. Advance in knowledge regarding gravity dams came only with a realization that the action of a gravity dam was by no means as simple as was at first thought. The section was first made rational by French engineers about the middle of the last century, has been greatly improved since, and is still being intensively studied. The normal section now tends towards a plain triangular profile (except for great heights) with a total batter varying from about 0.70 to about 0.90, and in some cases even more. The use of rubble and cut stone masonry, first with lime mortar and then with portland-cement mortar, has given way to the use of concrete, always now manufactured under accurate control. The Roosevelt dam was the last large gravity dam built in this country of stone masonry, although this material is still used in other countries for economic reasons.

Placement methods have had the greatest influence in bringing on the advent of large dams. Up to about 1903 the classical method of construction was to lay large stones on horizontal mortar beds and build up the vertical joints with mortar and spalls. Derricks were used almost entirely for handling on the job, materials being brought to them by rail, and later by cableway. Average progress was about 5 cu. yd. per derrick hour. About 1906 the use of cyclopean concrete came into vogue, the large stones being bedded on concrete and the vertical joints filled with concrete and spalls. This procedure doubled or trebled the output per derrick, as well as requiring less skilled labor. After about 1910 the vogue of cyclopean concrete began to diminish due to the development of larger concrete mixers which made possible the practice of passing moderate size rocks through the mixer, with great economy of time and labor. The concrete in earlier dams was generally placed by chuting, a method of placement which had an enormous vogue for all types of concrete construction from about 1910 to well into the '20s, but Duff Abram's classical researches in concrete led indirectly to the abandonment of this method, which required an excessive amount of water and led to reduced strength for a given amount of cement. Bucket placing from cableways and the use of conveyors subsequently made possible the use of a much drier concrete, and the recent development of vibrators has removed the objection of unworkability of the dry mix called for in modern specifications for concrete.

Belt conveyors were used in the Spaulding dam about 1913, and perhaps even earlier, but only with the object of gaining distance and height, for the modern vogue of dry concrete had not then appeared.

Mass handling of aggregates and of cement has improved greatly in recent years. Bagged cement on large jobs has been replaced by bulk cement, sometimes pumped through pipes for distances as great as a mile. As regards construction details, early gravity dams were not generally provided with any drainage in the body of the dam, the downstream portion of which was sufficiently pervious to prevent the accumulation of pressure. The provision of drains from the foundation plane, however, was common. But the use and improvement of concrete brought with it the disadvantage of

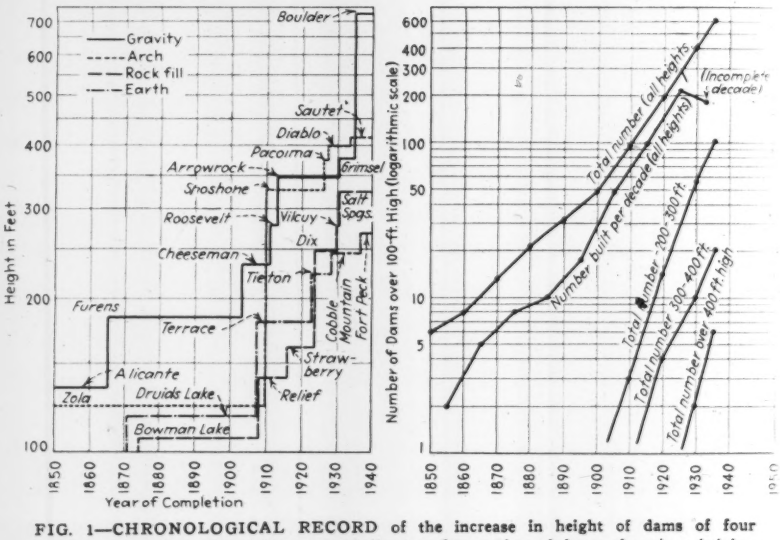


FIG. 1—CHRONOLOGICAL RECORD of the increase in height of dams of four major types, and, at the right, curves indicating the number of dams of various heights over 100 ft. built since 1850

impermeability of the downstream portion of the dam, which prevented the escape of whatever water might find its way into the upstream face. To overcome this difficulty, drainage of the body of the dam as well as the relief of underpressure has been fairly general for the last 25 or 30 years. Another disadvantage of mass concrete as compared with rubble masonry was the much greater shrinkage that developed due to the more rapid deposition of the mass, with less opportunity for escape of heat, and the smaller proportion of large stones which would absorb the heat released. Hence the use of contraction joints is now almost universal, and the rapid dissipation of setting heat has in some cases been achieved by artificial cooling.

Arch dams have benefited both from improvements in theory and in practice. Cain in this country and Guidi and others in Europe gave to the profession systematic studies of arch action under radial loads, all these studies being based on the original theory developed by Castigliano. More recently, studies in the division of load have led to the development of the trial load method of design. The discovery of the constant angle arch principle about 1912 opened the way for really large arch dams, which have grown both in height and in span. The height of arch dams has now exceeded 400 ft., and the length of arch alone in the projected Camp Verde dam is stated

FIG. 5—BOULDER DAM on the Colorado River far surpasses all others in height and in yardage of concrete. Grand Coulee Dam will surpass it in volume.

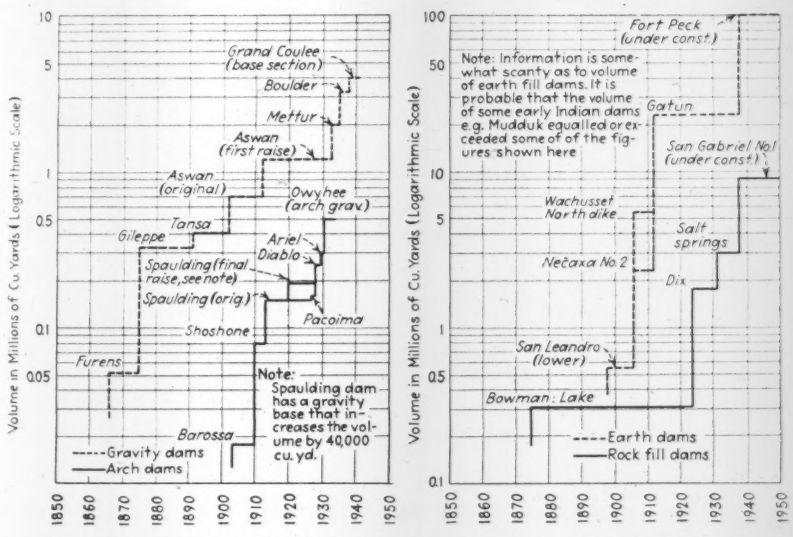


FIG. 4—INCREASE IN VOLUME of the four major types of dams over 100 ft. high.

to be over 1,100 ft., with a total crest length of about 1,700 ft. The grouting of contraction joins in arches has ensured that adequate arch action does take place.

Earth dams have developed as a result of improvements both in handling methods and in soil studies. Core walls, where used, have been developed which allow some flexibility and in some instances provide for inspection. The use of sheetpiling and cutoff walls in intercepting subsurface leakage has made eligible many sites which heretofore were considered inadmissible. Improvements in spillways and in outlets have aided not a little in making earth dams more secure.

The growth in size of rockfill dams has depended largely upon improvements in explosives, quarrying methods and handling. Face slabs are now scientifically designed to provide strength and watertightness together with flexibility.

The buttressed dam has had a rapid development in the present century. The first multiple arch dam was built over 100 years ago, but found only one or two imitators until near the end of the first decade of this century. Like the arch dam, it has benefited equally from refinements in theory and practice, as has also the slab type of dam.

All dams have benefited from great improvements in the practice of grouting foundations. In some cases as much as 15,000 tons of cement have been used in grouting rock foundations. Other grouting methods have been developed in cases of leakage through large cavities or underground passages, and the chemical method of solidifying deep deposits of sand and gravel under rockfill dams has recently been used with success.

Table 1, containing a listing of more than 600 dams over 100 ft. high already constructed or started, and a few projected dams, is believed to be fairly complete, and even allowing for inevitable deficiencies (which would ap-

ply mainly to the less important dams) some interesting conclusions may be derived from a study of the data there presented.

The data may first be summarized as to height and type of dam, as shown in Table II, which does not include proposed dams. This table shows the overwhelming predominance of the gravity dam (49 per cent of the total number), this predominance being more marked in the greater heights.

Fig. 1 shows at the left the increase in height of dams of different types, and it will be noticed that the gravity dam has been exceeded in height only twice and then for short periods. The lead is held by the Boulder Dam, where it is likely to remain for some time.

The actual volume of prominent dams, as shown in Fig. 2 is even more striking than the increase in height. From Furens to Boulder, the mass of masonry in the most massive existing gravity dam has increased more than 60 times in about 60 years, while from Barossa to Owyhee (if this be classed as an arch dam), the mass of masonry in the most massive arch dam has increased twenty-seven times in twenty-seven years. Notable earth dams have shown increases in volume in three great jumps, Necaxa, Gatun and Fort Peck. The Wachusset North Dike, completed about the same time as the Necaxa Dam, exceeded it in volume, but this was due rather to great length than notable height. The mass of rockfill dams has also increased in a striking manner, although it is worthy of note that the quantity of rockfill in the largest completed rockfill dam (Salt Springs) has actually been exceeded by the quantity of concrete in the Boulder Dam.

The most striking advance of all has been in the number of dams. Only eighty years ago, the building of one large dam (and 100 ft. was then a large dam) was an event of some note, while in the decade 1920-30 over 200 important dams over 100 ft. in height were built in various parts of the world, and almost as many have been completed or commenced within the present decade. Fig. 2 shows clearly the increase in number of dams built per decade and in the total number. Since about 1900, the number of existing dams over 100 ft. high has practically doubled every ten years.

The number built per decade has also been split up in Table III according to the type of dam. This summary shows clearly the steady progress maintained by the gravity, rockfill and earthfill types of dam. The plain arch dam lagged in development for centuries and then forged ahead from a late start but was soon overshadowed by the constant angle arch dam. The tardy development of the arch dam in a way is surprising, in view of the wide use made of the arch for [illegible] and buildings by the Romans, and its wide diffusion throughout Europe; the tardiness no doubt is explained by the fact that the art of building arch dams was introduced into Europe by the Moors, who stabilized the gravity dam as the dominant type. Table III also illustrates the well-known fact that the multiple arch dam, which ten or fifteen years ago appeared to have such a promising future has somewhat fallen out of fashion. The small number of buttress and slab or Ambursen type dams does not indicate any lack of faith in this type of structure, for it is admittedly best suited for low heights, and an enormous number have been built for heights under 100 ft.

An analysis of the geographical distribution of the dams listed in Table I, makes it clear that even when considerable allowance is made for deficiencies in information available, there is scope for the building of a great number of dams in other countries as they develop. The rate of increase in dam building in the United States has been coincident with the exceptionally rapid development of this country, and such a rapidity of development may hardly be expected elsewhere.

TABLE I. SUMMARIZED DATA ON DAMS OF ALL TYPES OVER 100 FT. HIGH

Name	Location	Height and Type	Length	Content, Cu. Yd.	Acre-ft.	Year Completed
Aaensire	Norway	190 MA	690	.....	.....	1922
Agertalsperre	Germany	138 G	.....	.....	17,000	1929
Alcova	U. S. A.	181 E	900	1,500,000	.....	1937*
Alexander	Hawaii	140 E	620	580,000	2,500	1932
Alicante	Spain	134 G	190	.....	3,300	1584
Alpe Cavalli	Italy	136 RF	590	175,000	6,500	1924*
Alpine	U. S. A.	100 G	320	.....	4,600	1918
Almanor	U. S. A.	135 E		1,532,000	1,308,000	1915*
Ampollino I	Italy	122 G	.....	.....	48,000	1924*
Amsteg	Switzerland	107 CA	100	.....	160	1922
Anvox	Canada	137 MA	684	.....	28,000	1924
Apishapa	U. S. A.	112 E	600	315,000	18,500	1920*
Arapuni	New Zealand	210 G	.....	95,000	.....	1930
Ariel	U. S. A.	313 CA	1,300	300,000	222,000	1930
Arrowrock	U. S. A.	348 G	1,100	585,000	280,000	1913
Ashland (Reeder Gulch)	U. S. A.	112 CA	465	18,000	800	1928
Ashokan (Olive Bridge)	U. S. A.	252 G	1,000	390,000	300,000	1911
Ashokan Dike	U. S. A.	110 E	.....	.....	.....	1917
Aswan	Egypt	128 G	6,420	700,000	794,000	1902
		144 G	6,500	1,200,000	1,960,000	1912
		174 G	6,970	1,730,000	4,040,000	1934
Avon	Australia	226 G	.....	214,000	174,000	1927
Badana	Italy	185 G	705	120,000	3,600	1930?
Baitone	Italy	108 G	.....	.....	11,400	1930
Baker River	U. S. A.	250 CR	493	115,000	70,000	1925
Bakkadda	Algiers	141 RF	755	.....	27,000	1931
Balch	U. S. A.	100 CA	300	9,300	.....	1926
Ban	France	157 G	.....	.....	1,500	1870
Barbellino	Italy	175 G	.....	178,000	.....	1931
Barberine	Switzerland	252 G	867	275,000	31,000	1925
Barker	U. S. A.	172 G	625	140,000	12,000	1909
Barossa	Australia	112 CR	472	18,000	.....	1903
Barrett	U. S. A.	192 G	750	140,000	47,000	1922
Bartletts Ferry	U. S. A.	145 G	634	.....	.....	1925
Bau de Muggeris	Italy	190 G	.....	.....	29,000	1924?
Beaver Park	U. S. A.	108 RF	.....	.....	.....	1910?
Beetaloo	Australia	110 G	580	60,000	18,000	1890
Bee Tree	U. S. A.	177 E	.....	850,000	.....	1930?
Belle Fourche	U. S. A.	115 E	6,500	1,600,000	203,000	1909
Beni Bahdel	Algiers	164 MA	1,050	.....	34,000	1637?
Benopai	New Zealand	107 CR	.....	.....	.....	1920
Big Creek No. 1	U. S. A.	132 G	800	59,000	52,000	1913
Big Creek No. 6	U. S. A.	135 CR	.....	19,900	990	1915?
Big Dalton	U. S. A.	165 MA	480	45,000	1,300	1928
Big Eddy	Canada	120 G	.....	.....	.....	1925?
Big Meadows	U. S. A.	130 E	1,250	.....	1,300,000	Raised in 1926
Big Santa Anita	U. S. A.	225 CA	590	76,200	1,400	1926
Big Tujunga No. 1	U. S. A.	249 CA	585	108,200	6,200	1931
Big Wichita (Wichita Falls)	U. S. A.	100 E	7,500	1,500,000	500,000	1923
Bills Brook	U. S. A.	155 E	2,500	1,600,000	.....	1936?
Bionia	Italy	196 G	.....	.....	1,200	1916
Bissort	France	196 G	1,780	392,000	.....	1935
Blackbrook	U. S. A.	108 G	525	.....	.....	1905
Black Canyon	U. S. A.	184 G	1,134	79,000	.....	1924
Blue Ridge	U. S. A.	170 E	.....	.....	.....	1919
Bon Haniha	Algiers	165 RF	1,410	.....	51,000	1937?
Boonton	U. S. A.	114 G	2,150	255,000	26,000	1905

Footnotes on Table I: In the case of dams which have been raised, final height, volume and capacity are given with the date of raising in brackets. For a few notable dams, complete data are given. Queries indicate doubt as to year of completion or other data.

* Indicates failure of dam subsequent to completion.

Types of dams: G..... gravity dam.
CR..... constant radius or single center arch dam.
CA..... constant angle arch dam.
MA..... multiple arch dam, including multiple dome
B & S..... buttress and slab, or Ambursen type dam.
RF..... rockfill dam.
E..... earthfill dam (including hydraulic fill).

A few dams are of composite earth and rock fill type. In such cases they have been denoted by what appears to be the predominant material.

Many gravity dams and some of other types have wings or levees of earth or other type. Such have been listed only where notable.

TABLE I. SUMMARIZED DATA ON DAMS OF ALL TYPES OVER 100 FT. HIGH (Continued)

Name	Location	Height and Type	Length	Content, Cu. Yd.	Acre-ft.	Year Completed
La Boquila	Mexico	261 G	840	390,000	.....	1930?
Boschi	Italy	102 G	.....	.....	800	1930
Boulder (Lake Mead)	U. S. A.	726 G	1,180	3,250,000	30,500,000	1935
Bouquet Canyon	U. S. A.	213 E	1,150	3,421,300	36,200	1934
Bowman Lake	U. S. A.	107 RF	715	316,000	20,600	1875 (dismantled 1927)
Bowman North	U. S. A.	167 RF	680	300,000	63,000	1927
Bowman South	U. S. A.	103 CR	373	18,900	65,000	1926
Brasimone I	Italy	126 G	518	52,000	5,000	1911
Brekke	Norway	131 G	.....	.....	.....	1924
Bremba	Italy	115 G	.....	.....	1,600	1924
Brena	Spain	197 G	.....	.....	104,000	1935
Bridgeport	U. S. A.	100 E	.....	139,000	.....	1931
Bridge River	Canada	157 CR	.....	.....	1,250,000	1927?
Bristol	U. S. A.	100 B & S	525	.....	.....	1927 1933
La Bromme	France	142 CA	270	19,000	.....	1932
Buchanan	U. S. A.	137 MA	.....	.....	.....	1938?
Bucks Creek Diversion	U. S. A.	112 CA	500	19,200	16,400	1927
Bucks Creek Storage	U. S. A.	118 RF	1,220	351,700	103,000	1927
Buell	U. S. A.	105 E	550	137,000	.....	1927
Bullards Bar	U. S. A.	191 CA	440	48,900	31,500	1924
Bulileo	Chile	218 E	.....	.....	49,000	1928
Bull Run	U. S. A.	200 G	1,000	230,000	37,000	1928
Bully Creek	U. S. A.	129 RF	180	.....	10,000	1913*
Burnhope	England	131 E	.....	1,690,000	.....	1936
Burrenjuick	Australia	200 G	.....	320,000	772,000	1913
Burrator	England	106 E	361	.....	.....	1899
Buseo	Italy	169 G	.....	.....	6,000	1914
Butte City	U. S. A.	120 G	350	.....	600	1892
Cajalco	U. S. A.	193 E	2,584	3,400,000	100,000	1937?
Calandrino	Italy	138 G	.....	.....	3,800	1924
Calaveras	U. S. A.	215 E	1,300	3,460,000	100,000	1925
Calderwood	U. S. A.	230 CA	897	400,000	.....	1930
Calles	Mexico	240 CA	934	61,000	258,000	1928
Camarasa	Spain	333 G	469	283,000	89,000	1929
Camarillas	Spain	118 G	.....	.....	32,000	1935
Camplicciioli	Italy	269 G	900	301,000	8,100	1929
Camp Verde	U. S. A.	340 CA	1,139	arch	.....	proposed
			1,719	total	.....	
Campo Secco	Italy	110 G	1,140	72,000	.....	1930
Cancano di Fraele	Italy	174 G	.....	.....	16,000	1924*
Cardenello	Italy	245 G	850	146,000	.....	1931
Caneadea	U. S. A.	140 CA	620	66,000	28,000	1928
Canning	Australia	218 G	.....	.....	.....	1936
Careser	Italy	196 G	1,400	.....	13,500	1932
Caritaya	Chile	125 RF	.....	.....	22,000	1929
Carite	Porto Rico	105 E	520	200,000	.....	1914
Carmen	Chile	246 RF	.....	.....	89,000	1929
Carpenter	U. S. A.	115 G	1,164	.....	100,000	1931
Castillon	France	327 CR	525	218,000	.....	1930*
Castrola	Italy	226 MA	680	.....	.....	1923
Cataract	Australia	192 G	810	146,000	76,000	1908
Cat Creek	U. S. A.	120 CA	237	6,000	.....	1931
Catavi	Bolivia	100 E?	.....	.....	15,000	1915
Cave Creek	U. S. A.	107 MA	1,732	18,700	14,000	1922
Cedar River	U. S. A.	200 G	1,000	.....	.....	1915*?
Ceppo Morelli	Italy	147 CA	.....	.....	400	1930
Ceresole Reale	Italy	160 G	.....	162,000	27,000	1930*
Chambon	France	450 G	1,080	392,000	13,000	1935
Chankapur	India	140 G	583	81,000	34,000	1911
Chartrain (Tache)	France	175 G	.....	.....	3,600	1892
Chavanon	France	279 G	1,180	445,000	170,000	1925*
Cheat Haven	U. S. A.	100 G	.....	180,000	87,000	1920*
Cheeseman	U. S. A.	236 G	710	103,000	80,000	1904
Chelsea (Bitobee)	Canada	100 G	1,600	170,000	1,980,000	1927
Cheoah	U. S. A.	230 G	770	.....	7,500	1919
Cher	France	154 G	323	.....	21,000	1907
Chichester	Australia	135 G	.....	119,000	13,500	1915*
Chiusella	Italy	154 CA	.....	.....	1,400	1924
Chute-a-Caron (Saguenay)	Canada	200 G	3,015	460,000	.....	1931
Cingiano	Italy	170 G	480	67,000	4,500	1930
Cismon	Italy	144 CR	.....	.....	3,200	1910
Clear Creek (Continental)	U. S. A.	100 E	340	.....	32,000	1935
Cle Elum	U. S. A.	130 E	750	1,235,000	356,000	1932
Cobble Mountain	U. S. A.	246 E	890	1,800,000	812,000	1932
Coghinas	Italy	164 G	610	144,000	164,000	1924
Cogoti	Chile	246 RF	.....	760,000	83,000	1932
Colombera	Italy	197 G	230	37,000	1,400	1924
Combamala	Italy	138 B&S	310	15,000	300	1916
Comelico	Italy	146 CA	.....	.....	500	1933
Conchas	U. S. A.	230 E	2,609	7,300,000	800,000	1937?
Concow (Lake Willenor)	U. S. A.	100 CA	275	6,300	.....	1925
Conklingville (Sacandaga)	U. S. A.	100 E	1,100	790,000	690,000	1930
Conowingo	U. S. A.	100 G	1,525	.....	57,000	1927
Coolgardie	Australia	120 G	755	.....	17,000	1902
Coolidge	U. S. A.	249 MD	600	204,000	1,300,000	1929
Copco, No. 1	U. S. A.	257 G	420	70,300	77,000	1922
Coquitlam	U. S. A.	100 E	1,200	545,000	180,500	1920?
Cordeaux	Australia	182 G	.....	.....	76,000	1925
Corfino	Italy	125 CR	.....	.....	600	1914
Costilla	U. S. A.	120 E	600	.....	15,000	1917
Cotatay	France	144 G	509	.....	700	1904
Coyote	U. S. A.	140 E	1,000	1,130,000	30,000	1936
Crane Valley	U. S. A.	100 E	1,800	907,000	50,000	1910
Crocodile River (Hartebeestpoort)	South Africa	198 CA	350	.....	136,200	1923
di Crosis	Italy	131 G	.....	.....	.....	1910?
Cross River	U. S. A.	170 G	772	161,000	33,000	1908
Croton Falls	U. S. A.	167 G	1,100	260,000	45,000	1911
Cubuk	Turkey	160 G	830	.....	9,800	1935
Cucharas	U. S. A.	125 RF	.....	.....	.....	1937?
Culimo	Chile	124 E	.....	.....	8,000	1929
Cummum	India	102 E	.....	.....	.....	1900
Cushman, No. 1	U. S. A.	275 CA	1,100	90,000	460,000	1925
Cushman No. 2 (Potlatch)	U. S. A.	240 CR	500	.....	.....	1930
Dales Dike	England	102 E	1,254	.....	2,680	1864*
Davis Bridge	U. S. A.	200 E	1,250	1,900,000	116,000	1924
Deadwood	U. S. A.	113 CR	700	.....	101,000	1930
Deer Creek	U. S. A.	112 CA	270	.....	.....	1928
Delta	U. S. A.	100 E	1,100	.....	63,000	1910?
Derwent	England	212 G	1,100	364,000	8,000	1929
Devils Gate	U. S. A.	140 G	310	.....	6,700	1920
Diablo	U. S. A.	400 CA	1,142	350,000	90,000	1928
Diemeltalsperre	Germany	112 G	636	.....	16,000	1923
Dix (Harrodsburg)	U. S. A.	250 RF	910	1,750,000	300,000	1924
Dnieprostroy	Russia	168 G	2,500	950,000	900,000	1932
Dodder	Ireland	115 E	.....	.....	.....	1900?
Deiras	Spain	290 G	.....	.....	.....	1935
Don Martin	Mexico	165 E	4,040	2,500,000	1,124,000	1931
Don Pedro	U. S. A.	284 G	1,040	296,500	289,000	1923
Dover	U. S. A.	100 G	820	100,000	.....	1936?
Druids Lake	U. S. A.	119 E	.....	.....	1,300	1871
East Canyon	U. S. A.	170 CA	290	16,000	28,000	1916
East Park	U. S. A.	139 G	250	12,000	51,000	1911
Eagle Mountain	U. S. A.	2100 E	.....	2,360,000	.....	1931
Eagles Nest (Cimarron)	U. S. A.	120 CR	300	26,000	78,000	1917
East Beaver Creek	U. S. A.	100 E	580	.....	.....	1932
Echapre	France	121 G	541	.....	800	1898
Echo	U. S. A.	125 E	1,800	1,400,000	74,000	1929
Edertalsperre	Germany	157 G	1,310	390,000	164,000	1913
Eel River (Scott)	U. S. A.	135 G	765	107,600	64,900	1921
Eguzon	France	200 G	1,000	274,000	44,000	1927
El Capitan	U. S. A.	240 E	1,200	2,679,700	118,000	1934
Elephant Butte	U. S. A.	306 G	1,155	635,000	2,637,000	1916
Eleven Mile Canyon	U. S. A.	112 CR	400	50,000	11,500	1932
El Vado	U. S. A.	212 RF	.....	607,000	198,000	1935
Emigrant	U. S. A.	127 CA	430	15,200	8,000	1924
Encino	U. S. A.	127 E	1,027	501,000	3,300	1924
Englewood	U. S. A.	110 E	4,700	3,500,000	209,000	1921
Enneppe	Germany	134 G	880	124,000	8,500	1904
Esperanza	Mexico	137 G	580	55,000	.....	1920?
Exchequer (Lake McClure)	U. S. A.	326 G	955	350,000	289,000	1926
Fairmont	U. S. A.	121 E	1,300	607,000	6,500	1927
Fifteen Mile Falls	U. S. A.	117 G	850	.....	.....	1939
Fisch	Italy	108 M A	.....	.....	2,400	1924?
Flathead	U. S. A.	200 G	630	.....	.....	1934?
Florence Lake	U. S. A.	149 MA	3,160	57,000	64,000	1926
Fort Peck	U. S. A.	270 E	9,000	130,000,000	19,500,000	1937?
Friant	U. S. A.	252 G	3,800	1,328,000	400,000	proposed
Fuensanta	Spain	272 G	.....	.....	192,000	1935
Furens	France	184 G	330	52,000	1,300	1866
Furlo	Italy	164 CR	.....	.....	1,600	1922
Fusenko	Chosen, Japan	250 G	1,308	640,000	.....	1930
Fusino	Italy	196 G	.....	.....	160	1924?
Gabiet	Italy	135 G	790	104,000	4,000	1922
Lake Lure	U. S. A.	122 MA	585	40,000	.....	1927
Lake Manchester	Australia	129 G	580	58,000	26,000	1916

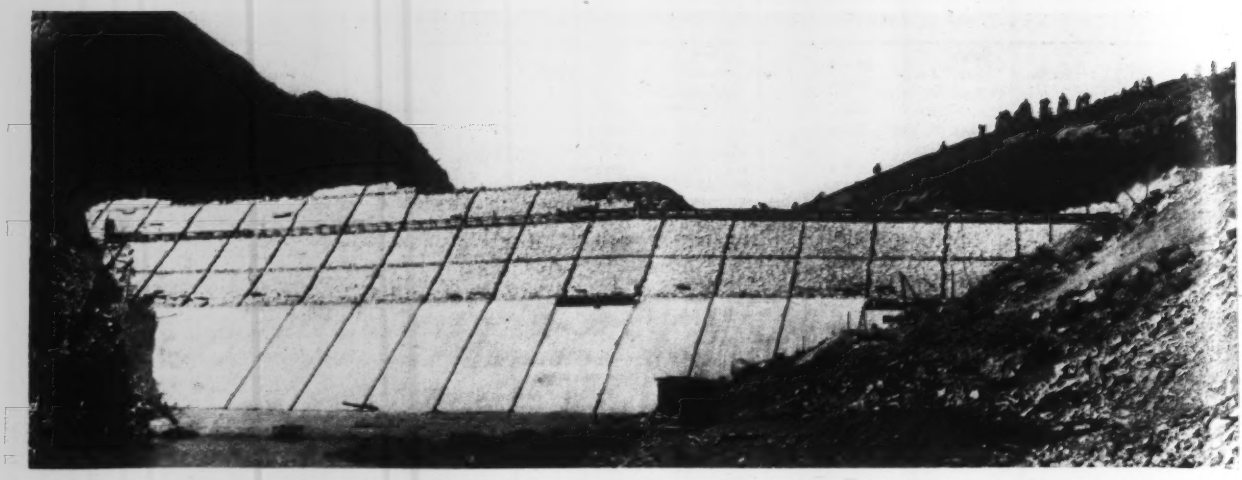


FIG. 6—SALT SPRINGS DAM on the Mokelumne River in California is the highest rockfill dam yet built. The completed dam, here shown under construction, is 325 ft. high. It will be exceeded in height by San Gabriel Dam No. 1 which is to be 375 ft. high.

TABLE I. SUMMARIZED DATA ON DAMS OF ALL TYPES OVER 100 FT. HIGH (Continued)

Name	Location	Height and Type	Length	Content, Cu. Yd.	Acre-ft.	Year Completed
Garcia	Mexico	160 G			104,000	1928?
Gatun	Panama	115 E	7,700	22,960,000	4,413,000	1912
Geigenbach (Voigtland)	Germany	138 G	900	144,000	2,600	1908
Gelmer	Switzerland	114 G	1,170	106,000	.....	1930?
Gembong	Java	100 E	1,640	288,000	.....	1933?
Gem Lake	U. S. A.	112 MA	640	8,500	17,200	1916
Gemelli	Italy	111 G		42,000	1,200	1924?
Germantown	U. S. A.	100 E	1,210	865,000	73,000	1921
Ghost River	Canada	108 G	4,975	.....	.....	1929
Ghrit	Algiers	213 RF	1,310	.....	202,000	1932?
Gibraltar	U. S. A.	185 CR	950	60,000	13,700	1920
Gibson	U. S. A.	195 CR	900	160,000	105,000	1928
Gilboa	U. S. A.	160 G	1,300	450,000	60,000	1927
Gileppe	Belgium	156 G	771	325,000	10,000	1875
Glenmaggie	Australia	100 G		80,000	150,000	1929
Gleno	Italy	164 MA	730	.....	5,000	1922*
Glines Canyon	U. S. A.	200 CA	555	20,000	43,000	1927
Glorbach	Germany	105 G	550	43,000	1,600	1904
Goldentraum	Germany	115 G	520	.....	.....	1930?
Goose Creek	U. S. A.	145 E	1,050	.....	73,000	1913
Gordon Valley	U. S. A.	104 E	600	.....	10,000	1926
Gorzente (Lago Lungo)	Italy	148 G	492	.....	3,000	1883 (1903)
Gran Cheurfas	Algiers	131 G	508	.....	13,000	1884* (since repaired)
Grand Coulee	U. S. A.	540 G	4,100	10,000,000	9,610,000	1938?
(Base section only being built now with vol. of about 4 million cu. yds.)						
Grand Rhus	France	148 G	.....	.....	.....	1925?
La Grange (Turlock)	U. S. A.	127 G	320	39,000	.....	1894
Gravelly Valley	U. S. A.	105 G	.....	.....	73,000	1920?
Greenville	U. S. A.	140 E	.....	.....	.....	1920*?
Grimsel (Spitallamm)	Switzerland	377 G	810	445,000	81,000	1931
Grizzly Creek	U. S. A.	120 CA	500	17,000	1,200	1927
Guajabal	Porto Rico	120 B & S	920	44,000	10,000	1913
Guajataca	Porto Rico	110 E	900	.....	28,000	1924
Guerde del Pozo	Spain	108 G	.....	.....	130 000	1935?
Guerledan	France	150 G	700	135,000	.....	1930
Guernsey	U. S. A.	105 E	560	512,000	72,000	1928
Gulf Island	U. S. A.	110 G	1,323	90,000	92,000	1925
Habra	Spain	125 G	1,476	.....	.....	1873*
Hamilton	U. S. A.	154 MA	8,377	.....	1,000,000	1937?
Hamiz	Algiers	134 G	532	.....	.....	1885
Hardy	U. S. A.	120 E	.....	.....	.....	1931
Harrowgate (Nidd)	England	100 G	900	.....	.....	1930?
Hasperbach	Germany	111 G	850	74,000	1,600	1904
Hauser Lake	U. S. A.	132 G	490	85,000	.....	1912
Hemet	U. S. A.	135 G	280	32,300	14,000	1895
(subsidiary earth dam failed 1927)						
Henner (Meschede)	Germany	124 G	1,200	138,000	9,000	1905
Henshaw	U. S. A.	117 E	650	500,000	203,000	1923
Herbringhauser (Barmen)	Germany	112 G	700	53,000	1,600	1900
Hijar No. 1	Spain	141 G	236	.....	5,000	1880
Hijar No. 2	Spain	141 G	.....	.....	9,000	1880

Name	Location	Height and Type	Length	Content, Cu. Yd.	Acre-ft.	Year Completed
Hobart	Australia	109 G				1892?
Hogan	U. S. A.	137 CA	1,300	122,000	76,000	1928
Holter	U. S. A.	110 G	1,362	.....	.....	1910
Hone (Belice)	Italy	131 RF	.....	196,000	26,000	1923
Hong Kong	China	110 E	400	.....	.....	1931
Hoopes	U. S. A.	135 G	970	105,000	.....	1934
Horse Mesa	U. S. A.	305 CA	810	147,000	245,000	1927
Howden	England	242 G	1,080	286,000	7,600	1920
Huacal	Mexico	100 CR	140	.....	.....	1912
Hubbart (upper)	U. S. A.	131 CA	503	17,000	12,000	1923
Huintal	Chile	141 E	.....	.....	12,000	1928
Hume	Australia	142 E	4,260	4,300,000	1,250,000	1935
		106 G	720	578,000	.....	1935
Huntington	U. S. A.	169 G	.....	116,800	88,700	1912 / 1917
Hyrum	U. S. A.	100 E	540	427,000	.....	1935
Idaho Irrigation Co.	U. S. A.	135 E	.....	.....	.....	1915?
Irrigation Dam	Argentine	164 RF	1,180	.....	594,000	1934
Jandula	Spain	280 G	.....	.....	69,500	1930?
La Jogna (Monsalvens)	Switzerland	186 CA	250	.....	.....	1921
Johnstown	U. S. A.	110 E	.....	.....	.....	1931
Jordan	U. S. A.	125 G	2,066	.....	40,000	1929
Jordan River	Canada	126B&S	891	21,000	14,000	1912
Juncal (Montecito)	U. S. A.	160 CA	440	40,000	7,000	1930
Kaketo	India	106 G	3,435	223,000	64,000	1927
El Kansera	Algiers	206 G	592	248,000	224,000	1934
Kennet	U. S. A.	420 G	2,430	3,420,000	2,940,000	proposed
Kensico	U. S. A.	307 G	1,843	900,000	913,000	1916
Kerckhoff	U. S. A.	108 CA	570	23,000	4,200	1919
Keystone	U. S. A.	130 E	8,000	20,000,000	2,000,000	proposed
Klingenberg	Germany	131 G	.....	.....	13,400	1914
Kodayar	India	152 G	1,396	141,000	81,000	1906
Komotau	Austria	139 G	508	70,000	600	1904
Koon	U. S. A.	108 G	726	72,000	7,000	1932
Krishnarajah Sagara	India	146 G	8,600	1,115,000	1,110,000	1932
Lafayette	U. S. A.	170 E	1,855	2,000,000	11,900	1928
Laggan	Scotland	186 G	680	110,000?	.....	1934
Lago d'Arno	Italy	109 G	.....	.....	25,000	1910
Lago d'Avio	Italy	105 MA	.....	.....	12,000	1924?
Lago Goillet	Italy	115 G	.....	.....	8,000	1932?
Lago di Mezzo	Italy	102 G	.....	.....	300	1930
Lago Nero	Italy	112 MA	.....	.....	2,500	1924?
Lago Scuro	Italy?	131 CR	.....	.....	2,000	1924?
La Laguna	Chile	134 E	.....	.....	34,000	1926
Lahontan	U. S. A.	129 E	1,359	770,000	290,000	1914
Lake Christine	U. S. A.	100 E	.....	.....	.....	1900
Lake Fordyce	U. S. A.	140 RF	1,030	416,600	46,800	1927
Lake Hodges	U. S. A.	136 MA	558	18,200	37,700	1917
Lake Kemp	U. S. A.	100 E	.....	.....	.....	1923

TABLE I. SUMMARIZED DATA ON DAMS OF ALL TYPES OVER 100 FT. HIGH (Continued)

Name	Location	Height and Type	Length	Content, Cu. Yd.	Acre-ft.	Year Completed
Lake Pleasant (Frog Tanks)	U. S. A.	256 MA	1,975	103,000	173,000	1927
Lautaro	Chile	100 E	.....	.....	33,000	1926
Lavagnina	Italy	143 G	.....	.....	.....	1917
Lavezze	Italy	126 G	.....	.....	.....	1910?
Lehnmuhle	Germany	148 G	.....	.....	18,600	1927
Linville	U. S. A.	160 E	.....	.....	.....	1919
Liro	Italy	107 G	284	.....	.....	1930
Listertalsperre	Germany	131 G	.....	140,000	18,000	1912
Little Bear Creek (Lake Arrowhead)	U. S. A.	200 E	720	1,500,000	47,000	1922
Little Rock	U. S. A.	158 MA	.....	32,100	4,300	1928?
Lloyd (Bhatgar or Lake Whiting)	India	194 G	4,266	.....	556,000	1928
Loch Raven	U. S. A.	103 G	640	96,000	71,000	1914
Long Valley	U. S. A.	132 RF	520	510,000	163,000	1937?
Los Reyes	Mexico	100 E	.....	.....	.....	1920?
Lost Creek	U. S. A.	130 CA	360	11,000	5,800	1924
Lozoya	Spain	105 G	238	.....	.....	1852
Lyons	U. S. A.	100 CA	516	16,000	5,800	1930
Madden	Panama	220 G	900	.....	506,000	1933
Mad River	U. S. A.	130 CA	440	22,000	19,000	1937?
Malibu	U. S. A.	100 CR	.....	.....	.....	1924
Magic	U. S. A.	135 E	625	.....	192,000	1909
Malacca (Perak)	Malaya	143B&S	1,380	143,000	.....	1930
Maladevi	India	106 E	.....	.....	.....	1909
Manorburn	New Zealand	108 CR	.....	8,600	.....	1915
Manuherikia	New Zealand	110 RF	520	.....	8,000	1935
Marathon	Greece	177 G	935	224,000	33,000	1931
Mareges	France	295 CA	650	242,000	26,000	1935
Marakanawe	India	167 G	.....	.....	690,000	1923
Marklissa	Germany	141 G	427	84,000	162,000	1907
Marmore	Italy	138 RF	.....	.....	9,600	1924
Martin (Cherokee Bluffs)	U. S. A.	145 G	1,200	395,000	1,620,000	1926
Mauer (Bober)	Germany	203 G	918	332,000	40,000	1912
Mazoe	Africa	200 G	.....	.....	.....	1922?
McKay	U. S. A.	165 E	2,600	2,287,000	73,000	1928
Mediano	Spain	180 G	.....	.....	94,000	1935
Medina	U. S. A.	178 G	1,580	205,000	254,000	1913
Melones	U. S. A.	185 CR	591	92,900	112,500	1927
Melton	Australia	111 E	.....	.....	17,000	1913?
Mercedes	Mexico	136 G	535	28,000	12,000	1905
Mettur (Cauvery)	India	214 G	7,070	2,030,000	2,150,000	1934
Mezquital	Mexico	102 G	.....	.....	57,000	1925?
Mignane	Italy	167 G	.....	.....	11,300	1931?
Millbrook	Australia	106 E	.....	.....	13,400	1915
Misselbeck	U. S. A.	125 E	.....	.....	.....	1920?
Mitchell	U. S. A.	105 G	.....	.....	.....	1924?
Mohawk	U. S. A.	115 E	.....	.....	.....	1936?
Mohnetalsperre	Germany	151 G	2,010	440,000	109,000	1913
Molare (Zerbino)	Italy	150 G	.....	.....	14,000	1924
				(auxiliary dam failed 1935)		
Molato (Tidone)	Italy	170 MA	722	.....	10,500	1925
Montejaque	Spain	273 CA	208	35,000	33,000	1924
Morena	U. S. A.	167 RF	505	335,000	65,800	1911
						(1930)
Mormon Flat	U. S. A.	216 CA	416	43,000	90,000	1925
Morris (Cal.) (Pine Canyon)	U. S. A.	756 G	360	450,000	39,300	1934
Morris (Conn.)	U. S. A.	100 E	1,100	.....	.....	1910
Mouche	France	102 G	1,346	.....	5,300	1890
Mountain Dell	U. S. A.	150 MA	560	.....	.....	1917
						(1924)
Mount Bold	Australia	165 CR	.....	100,000	24,000	1934
Mudduk (Madag)	India	114 E	1,700	4,730,000	.....	1500
						(not now in use)
Mulungushi	Africa	117 RF	.....	175,000	92,000	1925
Mulholland	U. S. A.	204 G	933	173,000	4,200	1925
Mulsi	India	166 G	3,600	810,000	370,000	1929
Murray	U. S. A.	112 MA	900	8,200	5,900	1917
Namal	India	128 G	321	.....	48,000	1913
Narnallah	Baluchistan	165 G	189	73,000	9,600	1913
Narrows (Yadkin)	U. S. A.	216 G	1,150	525,000	.....	1917
Nederland	U. S. A.	172 G	.....	.....	.....	1909
Necaxa No. 2	Mexico	180 E	1,220	2,300,000	.....	1909
Necaxa No. 3	Mexico	175 E	.....	.....	.....	1909
Negro	Chile	148 RF	.....	.....	41,000	1930
Nepean	Australia	246 G	700	342,000	39,000	1930
New Croton (Quaker Bridge)	U. S. A.	238 G	710	855,000	92,000	1907
Neye	Germany	110 G	850	172,000	5,000	1908
Niederwartha	Germany	138 F	.....	719,000	2,400	1929
Nijar	Spain	101 G	.....	.....	.....	1850
Nizam Sagara	India	158 G	15,992	1,128,000	590,000	1931
Norris (Cove Creek)	U. S. A.	240 G	1,570	1,195,000	2,710,000	1935
Novaliches	Manila	100 E	.....	640,000	27,000	1929?
Ochoco	U. S. A.	126 E	1,000	541,000	45,000	1921
Ocmulgee River	U. S. A.	112 G	420	.....	.....	1915?
Oester	Germany	131 G	770	80,000	2,500	1906
Ogden	U. S. A.	100 MA	340	.....	.....	1896
Ondenon	France	123 G	420	.....	300	1904
Ordunte	Spain	161 G	.....	.....	18,000	1935
Osage (Bagnell)	U. S. A.	148 G	2,543	545,000	,000,000	1931
O'Shannassy	Australia	152 E	.....	.....	.....	1927
O'Shaugnessy (Cal.)	U. S. A.	430 G	900	660,000	350,000	1925
						(37)
O'Shaugnessy (Ohio)	U. S. A.	105 G	1,750	150,000	16,200	1921
Osmena	Philippines	100 CA	131	.....	.....	1913
Otay (lower)	U. S. A.	175 G	750	.....	58,000	1919
Oued Fodda	Algiers	288 G	590	350,000	182,000	1933
Oued Kebir	Algiers	115 RF	1,140	.....	21,000	1930?
Oued Ksob	Algiers	148 MA	.....	.....	24,600	1936?
Owl Creek	U. S. A.	122 E	.....	.....	.....	1930?

RODRIGUEZ DAM in Mexico is a buttress-slab dam of Ambursen type with a record height of 250 ft. for that type of structure. The dam has a cutoff wall sunk 300 ft. below stream bed in a narrow fault zone

TABLE I. SUMMARIZED DATA OF DAMS OF ALL TYPES OVER 100 FT. HIGH

Name	Location	Height and Type	Length	Content, Cu. Yd.	Acre-ft.	Year Completed
Pachica	Chile	207 RF	.....	.....	27,000	1929
Pack (Koellach)	Austria	108 G	656	.....	.....	1931
Pacoima	U. S. A.	380 CA	600	226,100	5,900	1927
Paddy Creek	U. S. A.	160 E	.....	.....	.....	1919
Palmdale	U. S. A.	175 MA	724	25,000	5,500	1924
Pardee (Lancha Plana)	U. S. A.	345 G	1,320	640,000	222,000	1929
Parker	U. S. A.	320 CR	800	260,000	717,000	1936?
Pas du Riot	France	113 G	.....	.....	1,000	1878
Pathfinder	U. S. A.	210 CR	425	60,200	1,070,000	1910
Patillas	Porto Rico	147 E	1,020	920,000	.....	1913
Patjel	Java	114 RF	360	104,000	39,000	1932
Pavana	Italy	177 MA	385	47,000	800	1925
Pend Oreille	Canada	?150 RF	.....	.....	.....	1932
Periyar	India	173 G	1,214	185,000	360,000	1897
Piano del Leone	Italy	102 G	.....	.....	3,500	1932
Pintanane	Chile	196 RF	.....	.....	23,000	1929
Pit River No. 3	U. S. A.	112 G	494	.....	36,000	1925
Pit River No. 4	U. S. A.	120 B & S	.....	42,700	2,000	1928?
Pigeon River (Waterville)	U. S. A.	200 CA	870	120,000	.....	1928
Pinet	France	114 G	550	115,000	.....	1928
Ponte Alto	Italy	124 CR	.....	.....	.....	1611 (1887)
Poona (Lake Fife or Khadakwasla)	India	130 G	3,431	360,000	84,000	1879
Portefiume	Italy	103 G	262	26,000	.....	1930
La Prele	U. S. A.	148B & S	330	22,500	24,000	1910
Prettyboy	U. S. A.	147 G	682	192,000	78,000	1934
Priest	U. S. A.	147 E	1,160	734,300	2,300	1923
Prince Alfonso	Spain	237 G	.....	.....	.....	1925
Provo	U. S. A.	180 E	.....	.....	145,000	1938?
Puddingstone No. 1	U. S. A.	140 E	.....	864,300	17,400	1928
Puentes	Spain	164 G	925	.....	.....	1791*
Pykes Creek	U. S. A.	100 E	.....	.....	14,900	1908
Quabbin Reservoir	U. S. A.	170 E	2,640	4,000,000	1,270,000	1938?
Quabbin Dike	U. S. A.	135 E	2,140	2,500,000	See Quabbin Reservoir	1938?
Queis	Germany	148 G	.....	.....	.....	1905?
Railroad Canyon	U. S. A.	100 CA	625	12,500	11,000	1928
Receleta	Chile	147 E	.....	.....	81,000	1928
Relief	U. S. A.	140 RF	509	137,000	15,100	1909
Rempen	Switzerland	104 G	.....	.....	.....	1924
Requena	Mexico	100 E	600	.....	.....	1919
Requiiada	Spain	171 G	.....	.....	53,000	1935
Richmond	Africa	200 G	.....	.....	.....	1923
Ricobaya	Spain	326 G	.....	500,000	960,000	1935
Ridgeway	Australia	190 CR	730	.....	800	1918
Ringedal	Norway	115 G	1,680	105,000	227,000	1918
Rio	U. S. A.	105 E	1,500	140,000	.....	1926
Rio Janeiro	Brazil	138 G	656	.....	.....	1916?
Rio Puerco	U. S. A.	125 G	.....	.....	205,000	1936?
Ripa	Italy	154 G	100	.....	.....	1916
Roohemolles	Italy	190 G	.....	214,000	27,000	1930
Rock Island	U. S. A.	108 G	4,400	200,000	.....	1932
Rodriguez	Mexico	250 B & S	2,200	240,000	111,000	1935
Roosevelt	U. S. A.	280 G	1,125	342,000	1,637,000	1911
Round Hill	U. S. A.	114 G	220	38,000	4,000	1901
Rumblar	Spain	213 G	.....	.....	102,000	1935
Ruskin	Canada	184 G	340	105,000	.....	1931
Ryburn	England	123 G	600	.....	.....	1932
Saale (Bleiloch)	Germany	213 G	550	.....	174,000	1931
Safe Harbor	U. S. A.	106 G	5,000	.....	.....	1932
Safford	U. S. A.	100 CA	130	970	150	1928
Saint Mark	France	157 G	580	90,000	.....	1931
Saints Peyres	France	196 G	608	157,000	27,000	1934
Salmon Creek	Alaska	168 CA	640	52,000	.....	1913
Salmon River	U. S. A.	200 CR	490	.....	228,000	1912
Salto	Italy	196 G	425	.....	70,000	1934
Salt Springs	U. S. A.	325 RF	1,300	3,000,000	130,000	1931
Saluda	U. S. A.	208 E	7,838	11,000,000	2,300,000	1930
Sanguineto	Italy	164 G	.....	.....	2,800	1930
San Antonio	Spain	269 G	670	351,000	188,903	1917
San Clemente	U. S. A.	107 CA	270	7,000	.....	1920
San Dimas	U. S. A.	130 G	.....	.....	2,400	1922
San Fernando (lower)	U. S. A.	142 E	2,050	2,827,000	18,900	1924
San Gabriel No. 1	U. S. A.	375 RF	1,670	10,260,000	56,000	1938?
San Gabriel No. 2	U. S. A.	255 RF	800	1,200,000	13,000	1935
San Jose	Mexico	151 G	592	.....	.....	1929
San Leandro (upper)	U. S. A.	185 E	683	1,250,000	41,400	1931
San Leandro (lower)	U. S. A.	135 E	560	622,000	13,800	1926
San Mateo (Crystal Springs)	U. S. A.	154 G	680	157,200	54,000	1888
San Pablo	U. S. A.	168 E	1,230	2,250,000	43,200	1920
San Pietro (Nitti)	Italy	180 CR	.....	.....	5,600	1926
San Petito	Italy	104 E	.....	.....	270	1921
San Roque	Argentine	114 G	1,180	.....	91,000	1911
San Salvatore	Italy	251 G	.....	.....	19,000	1932
Santa Cruz	U. S. A.	151 CR	502	.....	7,000	1931
Santa Caterina	Italy	174 G	590	117,000	5,500	1935
Santeetlah	U. S. A.	212 CA	1,150	195,000	131,000	1928
Santiago Creek	U. S. A.	130 E	1,400	789,000	25,000	1931
Santiago River	Mexico	142 MA	.....	.....	.....	1930
Sarrans	France	360 G	710	590,000	.....	1933
Santet	France	414 CA	263	130,000	106,000	1928
Savage	U. S. A.	167 G	.....	83,000	56,300	1908
Sawpit	U. S. A.	160 CR	539	56,200	500	1935
Scandarella	Italy	170 G	.....	.....	10,000	1927
Schluchtseesperre	Germany	207 G	940	.....	.....	1932
Schwarzenbach	Germany	213 G	.....	380,000	11,600	1924
Scituate	U. S. A.	180 E	3,200	2,500,000	.....	1924
Seminoe	U. S. A.	260 CA	540	163,000	910,000	1930
Sengbach (Gluder)	Germany	141 G	580	35,000	2,500	1926
Sennar	Sudan	129 G	9,900	556,000	517,000	1925
Seuferegg	Switzerland	138 G	940	92,000	.....	1920
Shasta River	U. S. A.	100 E	1,234	690,000	.....	1928
Shaver Lake	U. S. A.	173 G	2,222	275,000	126,000	1927
Sherman	U. S. A.	100 E	700	295,000	.....	1927
Shirawta	India	127 G	6,400	630,000	151,000	1922
Shoshone	U. S. A.	328 CR	200	79,000	456,000	1910
Silvan	Australia	136 E	2,100	1,600,000	32,000	1931
Sioule	France	100 G	394	.....	.....	1904
Solbergfoss	Norway	154 G	174	.....	.....	1924
Somerset	U. S. A.	110 E	2,100	1,000,000	62,000	1913
Sorpe	Germany	226 E	2,300	4,250,000	66,000	1931
Sosetalsperre	Germany	186 E	.....	.....	20,300	1931
South Spullersee	Austria	112 G	.....	.....	9,000	1924
Spanish Springs	U. S. A.	112 E	2,815	1,700,000	300,000	1911
Spaulding	U. S. A.	275 CA	780	192,000	74,500	1913 (1920)
Spiers Falls	U. S. A.	154 G	552	180,000	.....	1905
Standley Lake	U. S. A.	113 E	6,630	3,250,000	96,000	1912
Stewart Mountain	U. S. A.	212 CA	1,200	117,000	70,000	1930
St. Francis	U. S. A.	205 G	650	175,000	38,000	1926?
Stone Canyon	U. S. A.	175 E	567	729,900	8,100	1924
Stoney Gorge	U. S. A.	120 B & S	853	37,000	50,000	1928
Strawberry	U. S. A.	160 RF	612	330,000	18,000	1917
Stuetta	Italy	104 G	650	92,000	.....	1930
Sturgeon Pool	U. S. A.	108 G	.....	.....	.....	1926?
Sugarloaf (Eildon)	Australia	135 E	2,300	1,400,000	306,000	1927
Sun River	U. S. A.	120 CA	250	6,200	.....	1915
Sutherland	U. S. A.	180 MA	1,100	.....	21,000	1928
Suviana	Italy	293 G	.....	366,000	29,000	1932
Swansea	Wales	144 G	1,250	.....	.....	1905
Sweetwater	U. S. A.	129 G	380	20,500	18,100	1888 (1916)
Swift	U. S. A.	165 E	.....	.....	.....	1914
Tabeaud	U. S. A.	123 E	636	370,000	1,100	1902
Table Rock Cove	U. S. A.	140 E	910	600,000	28,000	1927
Taf Fechan	Wales	107 E	1,010	.....	12,500	1927
Talnan	Spain	272 G	.....	.....	176,000	1922?
Tallulah (Burton)	U. S. A.	116 G	400	.....	120,000	1914
Tansa	India	118 G	8,800	409,000	16,000	1891
Taylor Park	U. S. A.	190 E	.....	.....	.....	1937?
Temescal	U. S. A.	115 E	.....	.....	900	1868 (1886)
Tepuxtepec	Mexico	123 RF	900	108,000	405,000	1929
Ternay	France	125 G	525	.....	2,000	1868
Terrace	U. S. A.	180 E	605	500,000	16,800	1909
Tezcapa	Mexico	175 E	.....	.....	.....	1930?
Thava	Czecho-Slovakia	200 G	.....	292,000	130,000	1936
Thirlmere	England	112 G	.....	.....	.....	1893
Thokerwadi	India	195 G	1,875	278,000	295,000	1922
Tidoncello	Italy	148 MA	.....	.....	4,100	1925?
Tieton	U. S. A.	223 E	900	2,000,000	203,000	1924
Tiger Creek Afterbay	U. S. A.	112 CA	400	30,000	3,800	1930
Tiger Creek Regulating	U. S. A.	100 B & S	470	13,500	540	1932

TABLE I. SUMMARIZED DATA ON DAMS OF ALL TYPES OVER 100 FT. HIGH—(*Continued*)

Name	Location	Height and Type	Length	Content, Cu. Yd.	Acre-ft.	Year Completed
Torso	Italy	239 MA	930	200,000	330,000	1923
Titicus	U. S. A.	135 G	534	149,000	22,000	1895
Titicus	U. S. A.	102 E	985	.....		1895
Toba	Spain	118 G	.....	.....	32,000	1935?
Torre	Italy	118 CR	.....	.....	.....	1920?
Torside	England	100 E	.....	.....	.....	1890?
Tranco de Beas	Spain	295 G	.....	.....	406,000	1935?
Tremp	Spain	269 G	666	353,000	.....	1920
Truyere	France	315 G	.....	.....	.....	1933
Tunhovd	Norway	124 G	920	.....	.....	1920
Turano (Posticcioli)	Italy	212 G	720	.....	103,000	1934
Turrite (Gangheri)	Italy	141 CR	.....	.....	700	1922
Tuxedo	U. S. A.	121 CR	370	.....	.....	1917
Twin Falls	U. S. A.	137 G	.....	.....	72,000	1912
Tygart	U. S. A.	240 G	1,850	1,200,000	327,000	1937?
Tytam Tuck	China	127 G	1,195	129,000	5,300	1919
Urft	Germany	190 G	741	175,000	37,000	1903
Vado	Spain	180 G	.....	.....	31,000	1935?
Val de Infierno	Spain	116 G	330	.....	.....	1791
Valla	Italy	141 CR	.....	.....	.....	1925
Valtoggia	Italy	149 G	.....	.....	13,500	1931
Vamma	Norway	128 G	920	.....	.....	1915
Van Giesen	U. S. A.	100 CA	365	22,000	.....	1928
Vannino	Italy	160 RF	.....	.....	.....	1922
Vanivalasa Sagara	India	163 G	1,330	370,000	690,000	1907
Van Rynevelts Pass	Africa	113 G	1,250	.....	64,000	1924
Venina	Italy	170 MA	.....	.....	8,000	1926
Vermunt	Austria	172 G	1,260	188,000	.....	1932
Victoria	U. S. A.	120 MA	650	.....	.....	1931
Vilcuya	Chile	278 RF	.....	.....	65,000	1930
Villar	Spain	170 G	546	.....	15,000	1878
Vingeanne	France	114 G	.....	.....	.....	1885
Vranov	Czecho-Slov.	180 G	958	.....	.....	1933
Vyrnwy	England	136 G	1,350	260,000	45,000	1889
Wachusset	U. S. A.	228 G	971	267,000	193,000	1906
Wachusset North Dike	U. S. A.	100 E	.....	5,500,000	.....	1906
Waggital (Schraeh)	Switzerland	366 G	550	305,000	114,000	1925
Waitaki	N. Zealand	120 G	1,730	140,000	.....	1934
Waldeck	Germany	147 G	900	390,000	164,000	1921
Walnut Grove	U. S. A.	110 RF	.....	50,000	69,000	1887*
Wanaque	U. S. A.	100 E	1,500	830,000	103,000	1926
Waranga	Australia	190 E	.....	243,000	304,000	1920?
Warm Springs	U. S. A.	108 CR	549	19,400	170,000	1920
Webber Creek	U. S. A.	120 MA	320	.....	.....	1923
White Salmon	U. S. A.	125 G	471	.....	.....	1912
Willow Creek	U. S. A.	110 E	1,045	452,000	86,000	1910?
Wilson (Bhandardara or Lake Arthur Hill)	India	278 G	1,663	440,000	250,000	1926?
Wilson (Muscle Shoals)	U. S. A.	140 G	3,098	1,316,000	.....	1926
Wolf Creek	U. S. A.	130 G	1,400	.....	.....	1918?
Wyangala	Australia	190 G	.....	243,000	304,000	1934
Wyman (Bingham)	U. S. A.	120 E	2,400	.....	.....	1930
Yarrow	England	100 E	.....	.....	.....	1905?
Yesa	Spain	205 G	.....	.....	281,000	1935?
Zardezas	Algiers	115 G	.....	.....	12,000	1935?
Zillierbach	Germany	131 G	360	.....	.....	1935
Zola	France	123 CR	205	.....	1,200	1843
Zschopau (Kriebstein)	Germany	108 G	787	.....	.....	1929

NAMES OF DAMS APPEARING UNDER OTHER NAMES IN TABLE I

Name of Dam	Name used in Table I
Aare	Grimsel
Assuan	Aswan
Barmen	Herbringhauser
Barrenjack	Burrenjuick
Bagnell	Osage
Belice	Hone
Bhandandara	Wilson
Bhatgarh	Lloyd
Bingham	Wyman
Bitobee	Chelsea
Bleiloch	Saale
Bober	Manor
Burton	Tallulah
Catawba	Blue Ridge
Cauvery	Mettur
Cherokee Bluffs	Martin
Cimarron	Eagles Nest
Continental	Clear Creek
Cove Creek	Norris
Crystal Springs	San Mateo
Douglas	La Prele
Fordyce	Lake Fordyce
Gangheri	Turrite
Glyder	Senghach
Harrodsburg	Dix
Hartebeestpoort	Crocodile River
Hetch-Hetchy	O'Shaugnessy (Cal.)
Khadakwasla	Poona
Koettach	Pack
Kriebstein	Zschopau
Lago Lungo	Gorgente
Lake Arrowhead	Little Bear Creek
Lake Arthur Hill	Wilson
Lake Fife	Poona
Lake McClure	Exchequer
Lake Mead	Boulder Dam
Lake Whiting	Lloyd
Lake Willenor	Conconi
Madag	Mudduk
Meschede	Henner
Monsalvens	La Jogne
Montecito	Juncal
Muscle Shoals	Wilson
Nidd	Harrowgate
Nitti	San Pietro
Nueva Espana	Don Martin
Olive Bridge	Ashokan
Perak	Malacca
Pine Canyon	Morris (Cal.)
Posticcioli	Turano
Potlatch	Cushman No. 2
Quaker Bridge	New Croton
Reeder Gulch	Andahla
Sacandaga	Conklingville
Saguenay	Chute-a-Caron
Schraeh	Waggital
Scott	Eel River
Shannon	Baker River
Spitallamm	Grimsel
Sukkur	Lloyd
Tache	Chartrain
Tidone	Molato
Turlock	La Grange
Voigtland	Geigenbach
Waterville	Pigeon River
Wichita Falls	Big Wichita
Yadkin	Narrows
Zerbino	Molare

TABLE II—SUMMARY OF TABLE I BY HEIGHT AND TYPE OF DAM

HEIGHT IN FEET	Gravity	Plain Arch	Constant Angle Arch	Multiple Arch	Buttress and Slab	Rockfill	Earthfill	Total
Over 400	4	.....	2	.....	.....	.....	.....	6
300-400	12	4	3	.....	.....	2	.....	21
200-300	56	4	14	4	1	8	12	99
100-200	225	30	33	29	9	28	121	475
Totals	297	38	52	33	10	28	133	601

TABLE III—PROGRESS IN NUMBER OF DAMS OF DIFFERENT TYPES

DECADE	Gravity		Plain Arch		Constant Angle Arch		Muntiple Arch		Buttress and Slab		Rockfill		Earthfill	
	No per decade	Total	No per decade	Total	No. per decade	Total	No. per decade	Total	No. per decade	Total	No per decade	Total	No per decade	Total
Previous to 1850	4	4	2	2	...	...	...	...	...	...	...	...	1	1
1850-60	1	5	...	2	...	...	...	...	...	...	...	...	...	1
1860-70	2	7	...	2	...	...	...	...	...	...	...	...	2	3
1870-80	7	14	...	2	...	..	...	...	...	...	1	1	2	5
1880-90	9	23	...	2	...	...	...	...	...	...	1	2	...	5
1890-1900	13	36	...	2	...	...	1	1	...	...	..	2	3	8
1900-10	32	68	1	3	...	..	...	1	...	...	1	3	13	21
1910-20	48	116	12	15	6	6	4	5	4	4	4	7	24	45
1920-30	83	199	16	31	32	38	23	28	3	7	14	21	49	94
1930-	97	296	7	38	15	53	3	31	3	10	17	38	39	133

How Shall the Height of Dams be Measured?

Suggestion of considerations relevant to definition of height — Recommendation from authoritative committee needed

THE QUESTION of what measurement to use in rating the height of any type of dam has become more and more involved as new types have appeared and dams of more complex design have been built. Deep fissures in the underlying rock that must be filled with concrete, sloping foundation and question as to location of the "axis" in arch dams, or dams of new types, are typical of the complicating factors. As the difficulty of rating height has increased, the need for a clear definition likewise has become greater.

Legal limitations and regulations are being imposed on dam construction that have a direct relation to height. At least one state (California) has a law which refers to dam height and, for purposes of the act, defines it. Unfortunately, the definition is based more on legal than on engineering needs. However, it emphasizes the fact that unless engineers develop and agree upon some definition they may find themselves limited by and obliged to work with the terminology imposed by others.

Special study needed

Present variation of practice appears to be great enough to warrant study of the subject by a special committee of recognized authorities in the field of dams, with a view to preparing a definition of dam height capable of universal adoption as standard practice. The range of current opinion is indicated in the following statement, which represents the views of a number of engineers whose work has been such that they can speak of dams with intimate knowledge. The editors' purpose in bringing together these views is not to suggest a definition but rather to show that there are questions at issue which justify study of the broad subject by a competent committee that could be recognized as authoritative.

The opinions obtained bear on two items: the foundation or low point from which to measure height, and top of dam, or high point. Naturally, the former point is the more difficult of determination, but in modern dams there is room for difference of opinion as to both top and bottom.

Because California law places dams "25 ft. in height or over" under the jurisdiction of the state engineer in the matter of safety, it has been necessary to have some legal definition of dam height in that state. This has been fixed as the elevation of the spillway crest above streambed, and streambed is described as the lowest point in the stream channel at the dam site. This definition probably serves the purpose for which it was intended but it is of little help to the designer.

Selecting the low point

There is general agreement that the old method of rating the height by beginning at "the lowest point in the concrete" has become obsolete. Small, deep potholes which would have been included under the old definition are now invariably excluded, as are even fairly wide fissures in the foundation. For example, in the bedrock underlying Owyhee Dam there is a fault zone which extends from the upstream to the downstream face, varies in thickness from 12 to 20 ft. and contains 35,600 cu.yd. of concrete. Although the concrete filling in this fissure goes down to a depth of 113 ft. below any other part of the structure, the Bureau of Reclamation does not include it in rating the dam height. The upstream cutoff trench, on the other hand, is included in the height because it is the custom of the Bureau to consider cutoffs as part of the height.

Where the foundation slopes either up or downstream, selection of a low point that will be representative is particularly difficult. Suggestions have been advanced that height measurement should begin at the point where the axis of the maximum section meets the foundation or, again, that the average base elevation in the maximum section should be used. One power company expresses this as "the average elevation of the excavated foundation at the deepest section of the canyon, exclusive of portholes or fissures." Although definite, this has the disadvantage that if the foundation has a sharp incline either upstream or downstream the "average" may not be a figure adequately representative for purposes of design.

A modification that has also been suggested is to measure from the intersection of the downstream face with the excavated foundation. However, this would not be the deepest point if the foundation happened to slope upstream. These suggestions need further consideration. Other points already are settled in practice by the fact of their universal adoption. For example, grouting done to supplement the cutoff adds nothing to the height even where large holes close together develop something approaching a continuous cutoff wall.

Unless definite advantage in referring the measurement to the dam axis can be shown, a height definition might well exclude that term because location of the axis is not always well established; arched dams and buttress dams offer opportunities for different interpretations of "axis." In structures of the buttress type there might be advantage in defining the axis as the vertical line through the downstream edge of the buttress crest.

The high point

Although less troublesome than selection of the low point, several interpretations are possible in fixing the high point, particularly where the spillway is in a separate structure and the top of the dam is carried up to a height considerably above spillway level. Years ago it was the custom to include parapets (presumably because they would act as flashboards if a great flood were to overtop the entire structure), but the custom now is to exclude parapets as well as any other concrete that may project above roadway level. Parapets or other architectural features never have been included in the lists of height of dams issued by the Bureau of Reclamation.

The level most frequently selected as the high point for height measurement is spillway crest. This often is qualified by the expression "or, to the top of flashboards or spillway gates if these be used." In some cases the roadway over the dam has been accepted as the level representing the upper limit of height and on some dams there is good argument in support of this limit. After all, the function of a dam is to resist water pressure and hence it is logical to define its height on some basis definitely related to that function.

In overfall dams the high point ordinarily is taken to be the top of the crest (or crest gates). This level determines the effective height of reservoir at low flow and ordinarily is termed "normal water surface."

Because dams vary so widely in crest design it might be desirable to use one high point for height measurement on one type of structure and another point on a structure of different type.

Seismic factor

Now that a seismic factor sometimes is taken into account in dam design, the proportions of the structure depend on debris load, depth of backwater, total mass of dam and other factors connected with height. One engineer makes a considerable point of studying the unbalanced fill as a factor in the ef-

even more careful consideration than the portion above tailwater; tailwater reduces the effective weight of the submerged portion by buoyancy without helping much by back pressure.

Two figures for height?

The stresses in a dam are a function of its depth below low water as well as of the height above that level. Dead load stresses are profoundly affected by the lower portion of such a structure as Parker Dam, for example, where a relatively large part of the volume is below low-water level. This illustrates the reason for suggesting the use of two definitions; there are two viewpoints from which the question of dam height is regarded: (1) the effective height in storing water and (2) the height that must be taken into account in stress analysis.

Doubtless for these reasons there is preponderance of opinion that no single dimension for height will be entirely satisfactory. Usually the suggestion is that one definition will indicate primarily the effect of the dam on water level and hence might be called "hydraulic height" while the other would convey information primarily of interest to the designer and perhaps might be "designed height." In answer to the objection that in comparative tabulations frequently only one column is allowed for height, the suggestion has been made that one height column would suffice if accompanied by a footnote explaining a symbol or symbols used in the height column to indicate the two kinds of height listed. For example, the letter "*H*" might indicate hydraulic height, i.e., height above river bottom (or original water level), while "*C*" might identify the figure given for height above the lowest point of the maximum section subject to stress analysis.

Not only has the question of dam height come up repeatedly in times past (*ENR*, Nov. 2, 1922, p. 728; Nov. 30, 1922, p. 946 and Sept. 3, 1936, p. 347), but doubtless it will continue to arise whenever there are new conditions or new needs for interpretation. Therefore, even after a satisfactory definition has been formulated by an authoritative body and has been adopted by the profession, it may prove desirable to have a standing committee ready to pass upon questions of proper rating of dam height whenever new conditions present a specific question. Such a plan would provide a continuing source of uniform and authoritative rating, would make comparisons definite, and would offer to state regulatory bodies a service which only the engineering profession can and should perform.

Parking Meters Find Favor In Expediting City Traffic

A novelty a year ago, the metered parking system has now been adopted by 15 cities as an aid in solving the traffic problem

WHEN Oklahoma City in July, 1935 introduced metered parking control by means of a device known as the "parking meter," it pioneered in a novel scheme for alleviating conditions imposed by congested traffic in urban business districts. While insufficient time has elapsed to evaluate the success of this system as a panacea for the parking problem, it is significant to note that within a period of one year parking meters have been placed in operation in 15 cities and four others are either installing or planning to use this device in the near future. These facts are contained in a comprehensive report on the subject of parking meters prepared by the U. S. Conference of Mayors, from which we extract the following:

The parking meter is mounted on a standard about 4 ft. high, one meter to each parking area. It is a coin clock device which varies slightly in operation between the several makes of meters now on the market.

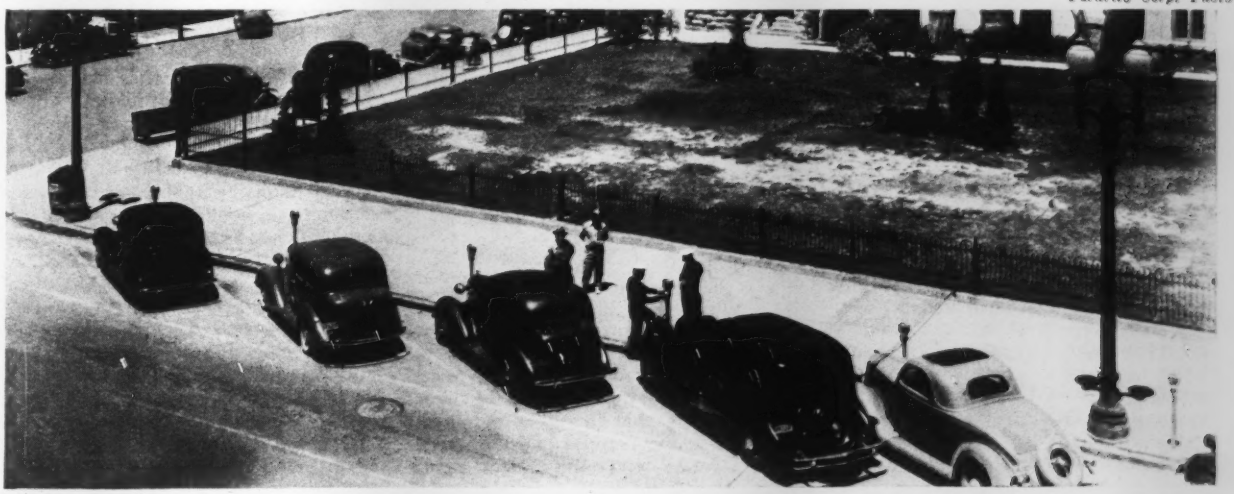
How the system operates

When a person enters a metered parking space, he is required to place in the meter slot a five cent coin which starts the registering mechanism. An indicator, or hand, is moved by the clock mechanism showing at all times the remaining parking time. When the period expires, a colored flag or disk either appears or drops out of sight (varying with the make of meter), and this unmistakably marks the presence of a violator.

The parking time allowed varies according to zones. In some cities 10, 15, or 20 minute zones have been established near banks or other locations where short time stops are made by a large number of persons. Elsewhere the

FIG. 2—BOTH angle and parallel parking spaces are adapted to meter regulations as shown in this Houston, Tex., installation.

Parkrite Corp. Photo



minimum period is 30 minutes with a maximum of one or two hours. The charge of five cents, however, is uniform regardless of the parking period.

Adequate parking space for parallel parking is generally conceded as 20 ft. and is so provided in most instances. Angle or diagonal parking spaces vary depending on the degree of angle which is practical in each case.

If a person leaves a metered space before the full parking time has expired, another motorist may drive in and use the space of the remaining time without cost. A person may not, however, legally put in another coin and use the space for additional parking time. It is claimed that because parking yards are cheaper for long periods, this provision is practically self-enforcing. Actually the system is designed as one of regulation and not the rental of street space.

Time limit enforcement

The ease with which violators of the parking meter ordinance can be detected is of course a principal argument in favor of the device. In all cases the meters are placed at the front end of the parking space and are high enough to be visible above the hood of the parking vehicle from the street side. Likewise the flag, disk, or other indicator marking a violator is also easily visible from the sidewalk so that either the motor patrol or foot patrol can readily check parking violations.

As pointed out above, it is a uniform provision of parking meter ordinances that a motorist may not legally extend his parking by inserting a second coin in the meter. This, states the report, is a reasonable and necessary provision inherent to the fundamental purposes of the meter system.

The penalty clause of violation of the parking meter ordinances varies between the cities. In some places, the fine is relatively low as in El Paso, where the maximum is $5; Toledo, $10; and Oklahoma City, $19 plus costs. Other cities impose exceedingly severe maximum fines as, for example, in Houston, Dallas, and St. Petersburg, where a maximum fine of $200 is authorized by the ordinance. Miami provides for a maximum fine of $50 or 30 days imprisonment or both. In Miami, however, as well as in Dallas, a violator may, within 24 hours, pay to the traffic bureau "a penalty for and in full satisfaction of such violation an amount equivalent to $1 multiplied by the number of periods of parking time established as a legal limit for such parking space during which such vehicle occupied such parking place in violation of any other provisions of this ordinance."

The legal theory of the parking meter ordinances is that it is a regulatory measure and the exercise of the police power with a fee to defray the cost of regulation. Nevertheless the revenue collected by the parking meters in the cities which have installed the devices has been far from insignificant.

Dual Parking Meter Co. Photo

FIG. 1—PARKING METER used in Oklahoma City. This is a coin clock device mounted on a metal stand about 4 ft. high.

Reports covering the five cities which have had meters in operation for the longest time reveal the following average daily receipts as reported by the Dual Parking Meter Co.:

City	Population	Number of Meters	Average daily receipts
Oklahoma City	200,000	523	50 cents
Dallas, Texas	300,000	1507	40.5 cents
El Paso, Texas	106,000	514	20.7 cents
St. Petersburg, Fla.	43,000	150	34.5 cents
Miami, Fla.	110,000	410	50 cents

The comparatively low daily receipts in the case of El Paso are ascribed to a larger coverage of metered area than is ordinarily recommended. When meters are installed in less congested areas where one or two hour parking is permitted, the receipts per meter will, of course, be less than when there is a more rapid turnover in the number of parkers.

Legality of meters

A not unimportant legal question, states the report, is involved with regard to the use of the parking meter. The legal theory of the parking meter ordinance is that it is a regulatory measure in the exercise of police power with a fee to defray the cost of regulation. It has not been definitely settled, however, whether the universal five cent meter charge can be justified as a mere regulatory fee, or whether, in fact, this charge is in excess of the reasonable cost of regulation.

CITIES USING THE PARKING METER SYSTEM

City	Date Installed	Total Meters
Oklahoma City, Okla.	July, 1935	952
Dallas, Texas	October, 1935	1507
St. Petersburg, Fla.	December, 1935	150
El Paso, Texas	January, 1936	514
Miami, Fla.	February, 1936	410
Houston, Texas	May, 1936	1000
Fort Worth, Texas	June, 1936	1000
Paducah, Ky.	June, 1936	167
Hutchinson, Kansas	June, 1936	150
Kansas City, Mo.	June, 1936	1500
Meadville, Pa.	July, 1936	175
Mobile, Ala.	July, 1936	150
Corpus Christi, Texas	August, 1936	200
Salt Lake City, Utah	August, 1936	500
Waco, Texas	August, 1936	250

Only two tests of this question have been made through the courts. One was the Oklahoma City case and the other was the Miami case now on appeal to the Supreme Court of Florida. In both cases the parking meter ordinances were sustained by the lower courts.

The report stated that according to information available there are now six companies competing in the parking meter field. All companies reporting quoted a price of $58 a meter plus installation costs. Similar terms of sale are being offered by most of the companies. The usual plan is to allow the meters to pay for themselves by turning over to the company a certain percentage of the meter collections. This percentage ranges from 50 to 85 per cent. The title to the meters remains in the company until the full terms of the contract are satisfied by the city. At least one of the concerns will install meters on a trial agreement wherein the city turns over to the company a certain percentage of the receipts, for which consideration it assumes full responsibility for removing the meters without cost to the municipality should the trial be deemed unsatisfactory.

Contract Award Governed By Drawing from Hat

DRAWING of its name from a hat awarded a contract for supplying the city of Niagara Falls with 264 barrels of cement to the Tiger Supply Co., on its bid of $615.

City Manager Robbins, in a communication to the common council asking permission to award the contract, stated: "A notice that bids were to be received was posted on the bulletin board, and invitations to bid were sent to seven dealers. Seven bids were received, the prices being all the same. The award was determined by drawing a name from a hat."

Although some objection was voiced in the city council to this method of award, the council voted to accept the decision of the hat.

Novel Practices In English Sewage Treatment

A visitor abroad finds innovations in the technique of sludge dewatering, the operation of oxidation devices, and in the design adopted for a major purification plant

By Willem Rudolfs,
Chief N. J. Sewage Experiment Station
New Brunswick, N. J.

WHEN Dr. Rudolfs visited England during the past summer, upon invitation to address the Royal Sanitary Institute, he found it opportune to spend several weeks studying sewage treatment methods and stream pollution abatement progress. From the wealth of information thus obtained, he prepared two articles for Engineering News-Record *of which this is the first. It is a recounting of those developments in disposal methods which impressed him most, and which he believes are of significant interest to American engineers. The second article, to be published subsequently, is a concise interpretation of English experience and practice in connection with pollution abatement legislation.* —EDITOR.

NEW sewage treatment processes and sewage disposal plants which incorporate novel features frequently hold greater interest for a visitor than do standardized installations, no matter how large or how well operated are the latter. This was the case during a recent inspection trip in England where the author observed several new installations which, in their departure from ordinary practice, are of particular interest. Among these were the Porteous process of sludge dewatering, combination oxidation schemes at Wakefield and Rotherham, and design features of the recently opened Mogden purification works. The following notes on these developments abroad are presented with the thought that American engineers may find in them some useful ideas.

The Porteous process

Renewed interest in steam heating sludge as an aid in dewatering and extraction of grease is evidenced by the investigations of the Porteous process at Halifax, Bradford and Sheffield. The "new" process, the revival of a scheme first suggested a quarter century ago, consists essentially of heating sludge in a boiler to a high temperature under steam pressure and then dewatering the product in filter presses.

The original idea is contained in an English patent (No. 3247) of 1911 which set forth a claim for a continuously operating apparatus with horizontal tubes. In the Porteous process the tubes are placed vertically to prevent clogging difficulties and a batch system of operation is employed. The originally patented scheme, known as the "Nils Testrup Process," was applied experimentally at Huddersfield during 1912-13 by the Electro-Metals Co., Ltd. In terming the process "wet carbonization of sludge" this company tried to include a means for recovering grease and making fertilizer from the easily dried sewage sludge; however, grease recovery by solvent extraction yielded an unsalable product, because no previous acidification of the sludge had been applied to liberate the fatty acids. The recovered grease, therefore, consisted mainly of lime soaps. The company had made its installation under the "no cure no pay" system and on account of many difficulties in plant operation and marketing of products the Huddersfield authorities requested removal of the plant in 1914. Nils Testrup, the inventor, was successful in obtaining large sums of money to promote his process; more than $2,500,000 of stock was sold in England and an attempt was made to form an American subsidiary capitalized at $2,000,000. When he later became the target of unfavorable criticism, Testrup resorted to sending bombs through the mails to silence his critics, and this resulted in his incarceration in prison where he died.

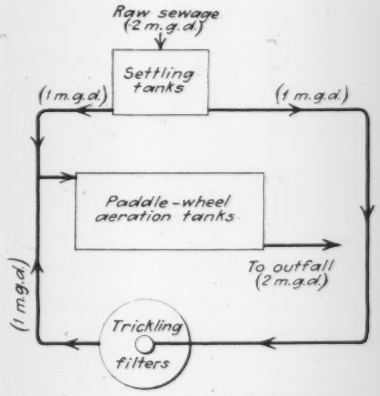
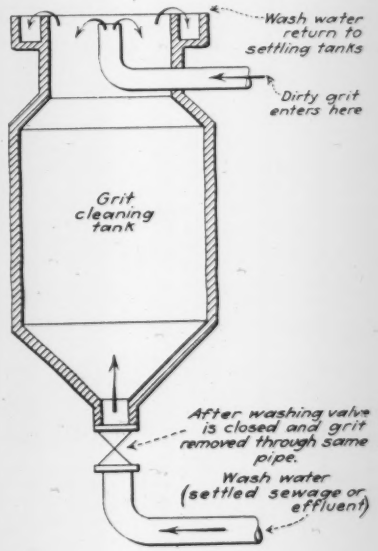


FIG. 1—"SPLIT AND RETURN" flow system used at the Rotherham plant. The settled sewage flow is divided, half going to the trickling filters and the balance to the bio-aeration tanks, where it is mixed with returned filter effluent.

FIG. 2—GRIT CLEANING scheme used at the Mogden plant. Each charge of grit is washed for 1¼ hr. which reduces the organic matter content to about 5 per cent.


Wash water return to settling tanks
Dirty grit enters here
Grit cleaning tank
After washing valve is closed and grit removed through same pipe.
Wash water (settled sewage or effluent)

Further experiments

During the years 1916-18 steam heating as an aid to grease extraction and dewatering of residual sludge was further experimented with at the Huddersfield plant. The pressed sludge cake contained about 10 per cent moisture, was more friable and in much better condition than cake pressed with the ordinary acid method, and required less time for pressing. This "wet carbonization" process originally tried on peat, was invented by a Swede, named Ekinburg. Although large sums were granted by the Swedish government as well as by the Iron and Steel Society of England to carry out experiments

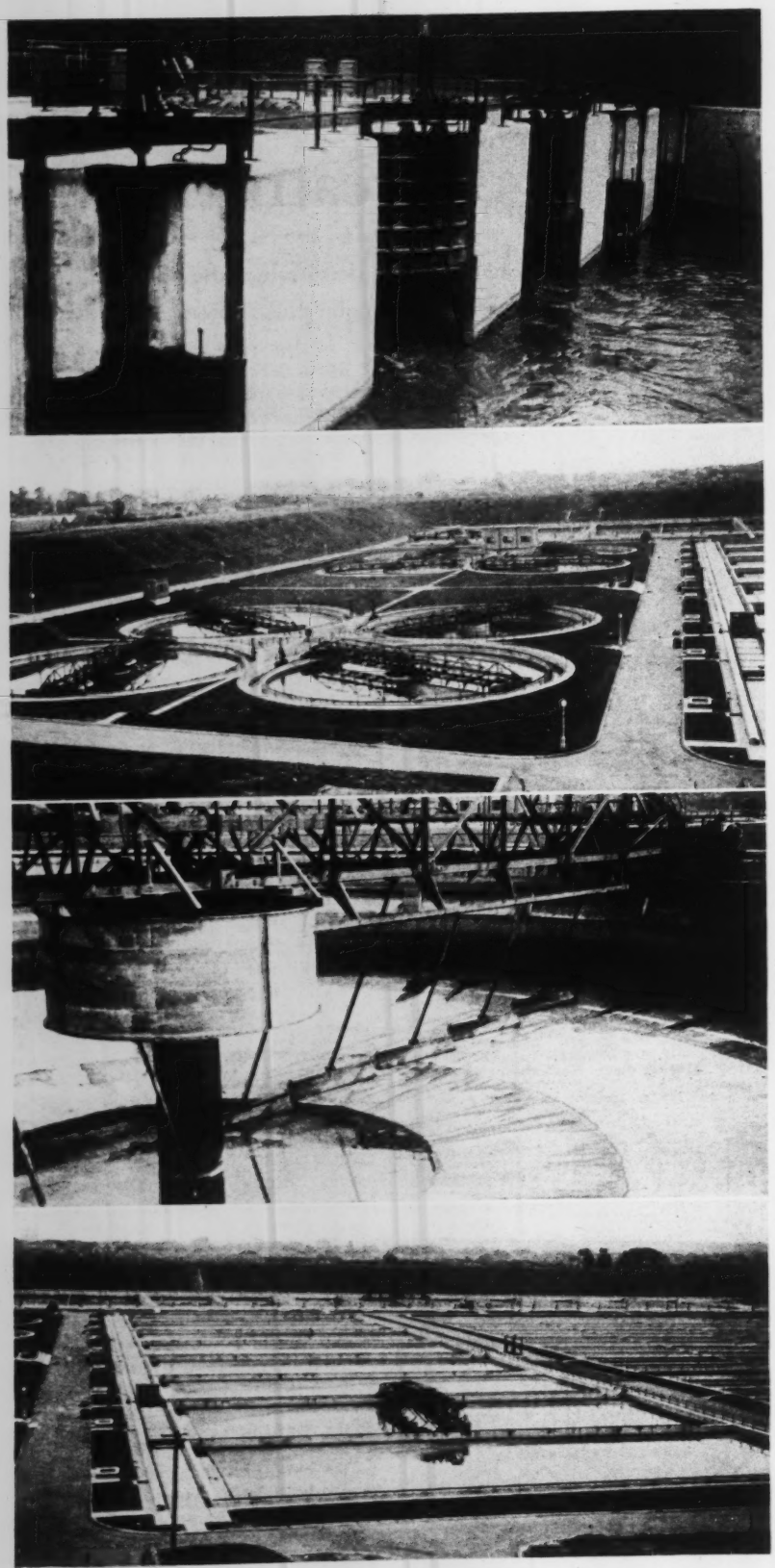


FIG. 3—VIEWS taken at the new Mogden plant showing from top to bottom: (a) Sluice gates at the grit chamber outlets; (b) primary pre-settling tanks; (c) Sludge removing device in the primary tanks; (d) Secondary pre-settling tanks provided with a sludge removing mechanism that can be moved to any tank unit by means of a transporter carriage.

and establish the system on a commercial basis, no success was ever achieved.

In the experimental studies of the Porteous process now being made at Halifax, sludge is steam-cooked for 75 minutes. The raw sludge, a mixture of three parts of secondary and one part activated sludge (combined on a dry solids basis), has a moisture content of 95 per cent. After cooking (thickening), the moisture content is reduced to about 89 per cent. This sludge is allowed to stand overnight, but it is probable that a cooling period of from 3 to 4 hr. would be sufficient. It is then pressed for one hour at 100 lb. per sq.in., and this produces a cake about 1½ in. thick with a moisture content of 10 to 15 per cent. Using less sludge a cake of one-half inch thickness can be pressed in about 20 min. without previous steam heating; on the other hand, from 8 to 24 hr. of pressure is necessary. The cake resembles coal brickets with a very slight tarry odor.

The steaming process is performed in a closed steel tank and consequently no odors are disseminated. The filter liquor, amounting to about 20,000 gal. per million gallons of sewage, is very black and dense, has little or no odor, and contains about one per cent of total solids; the biochemical oxygen demand is about 50,000 p.p.m. The nitrogen in the sludge is reduced from about 4 to 2 per cent by cooking. The residual cake consists mostly of fibrous material, hairs, etc. The highly putrescible liquor is returned to the sewage flow thus placing an additional load on oxidation devices which receive sewage containing large quantities of gas house, dye, wool and textile wastes.

Experimentation with the Porteous process at Bradford is along similar lines, while at Sheffield more intensive studies are in progress. No cost data were obtained but wherever exhaust steam is available, the dewatering charges would be low since sludge conditioning chemicals are not required. However, the additional load imposed by the filter liquor on oxidation devices may be appreciable, requiring plant extensions, greater volumes of air, and careful control.

Combined oxidation schemes

The necessity of producing well-stabilized effluents to prevent undesirable conditions in small streams has led to wider adoption of oxidation devices in the West Riding Rivers region and other sanitary districts. Trickling filters or mechanically aerated activated sludge processes by themselves do not always produce the desired results. For instance, at the Calder Vale works of Wakefield the sewage flow was formerly divided and treated separately either in trickling filters or paddle-

FIG. 4—PADDLE-WHEEL aeration channels at the Calder Vale Plant in Wakefield. Each of the two aeration tanks has 32 channels through which the sewage travels a distance of nearly ¾ of a mile.

wheel aeration tanks. The present method of operation, giving a higher degree of treatment, calls for aeration of all the sewage after which the activated sludge effluent is put through the trickling filters. The sewage, consisting of about half dye, wool-scouring and other trade wastes, is first settled for about 17 hr. so that the suspended solids remaining are about 150 p.p.m. The combined length of the two aeration tanks, divided into 32 channels from 5.5 to 6 ft. wide and 4.5 ft. deep, is nearly 1½ miles; the sewage in each tank travels for nearly ¾ mi., during which it is aerated successively by 68 paddle wheels, the shafts of which rotate at a speed of 15 p.p.m. (Fig. 4).

The effluent is then passed onto a battery of sixteen trickling filters, ten of which are 160 ft. square and six are 130 ft. square. The sewage distribution is effected by ten 115 ft. dia. revolving distributors and by sixteen 30-ft. distributors placed in the intervening spaces. About 83 per cent of the total filter bed area is thus utilized. The average depth of the beds is six feet and the dosing rate varies from 100 to 230 gal. per cu.yd. of stone.

Initial results

Although the remodeled plant has not been in operation very long, and the method not thoroughly tried, some results obtained with abnormal, normal and weak sewage were available and are shown in Table I. As stated before, the settling tanks have an average detention period of nearly 17 hr., the effect of which is reflected in the considerable reduction of suspended solids amounting to 70 per cent in the abnormal and 64 per cent is the ordinary sewage. In spite of these long detention periods the oxygen absorption figures are materially reduced by the settling process. The passage of aeration tank effluent through the filters affects oxidation as evidenced by a further reduction of oxygen requirements, but especially so in the reduction of ammonia and the production of nitrates. The effect on suspended solids is not of such great importance.

Rotherham system

At Rotherham (Aldwarke plant) the oxidation devices are operated under a scheme of what might be called a "split and return" system. The sewage flow of 2 m.g.d., produced by a population of 74,000, is entirely domestic. The plant includes screens, grit chambers, settling units, paddle-wheel aeration tanks, trickling filters, final settling tanks and sludge digestion tanks. The settling tank detention period is about twelve hours. The activated sludge units were built to treat an average flow of 600,000 gal. daily (aeration time varying from ten to twelve hr.), and the remaining flow was applied to trickling filters. These filters are rather shallow, varying in depth from 3.7 to 5.0 ft. deep. Operating in this fashion purification results were relatively poor.

Finally, a scheme was evolved whereby the 2 m.g.d. flow from the settling tanks was divided equally, half going to the bio-aeration tanks and the balance to the trickling filters. The effluent from the trickling filters is then returned and mixed with that portion of the pre-settled sewage passing to the aerator. The general arrangement of flow is shown in Fig. 1. with this method of operation the effluent produced is clear and sparkling, its quality far surpassing that obtained when the aeration units were handling 700,000 gal. of pre-settled sewage only.

Evidence of the improvement is shown in the average yearly oxygen consumed figures for 1934 (before returning trickling filter effluent), compared with the results for the year 1935 as well as those for the first half of 1936 when trickling filter effluent was returned and a greater volume treated by the bio-aeration systems, (Table II). The oxygen consumed figures (in p.p.m.) are used for comparison because this is the British standard for purification.

Before the trickling filter effluent was returned to the aeration tanks, considerable trouble was experienced with bulking of sludge. After the new method of operation was inaugurated no further troubles of this kind were experienced. The stated effects leave considerable room for speculation in regard to the reasons for the improvement. An interesting fact is that the effluent of the filters normally contain about ten p.p.m. of nitrates, while the activated sludge effluent contains about one p.p.m. By returning the trickling filter effluent the activated sludge-sewage mixture is thereby provided with about 75 lb. of nitrates a day. Whether the supply of this possible source of oxygen, or the fact that effluent from the trickling filters contains a balanced flora and fauna, capable of reinforcing the organisms in the sludge of the aeration units, or that a combination of these two factors are of importance in the greater stabilization of effluent and sludge, remains to be answered. In the meantime it would be of practical interest to determine whether the addition of nitrates to a bulking sludge would retard this undesirable condition; in this connection it will be recalled that O'Shaughnessy's work indicates that the reduction of nitrates intensifies bulking.

Incidentally, it was found at the Rotherham plant that about 1,000 p.p.m. suspended solids in the mixed liquor was best; higher or lower concentrations produced poor results. This is similar to results obtained with surface aeration units studied in this country.

The new Mogden plant

In January, 1936 the Mogden (West Middlesex, London) sewage treatment plant was placed in operation with a flow of 2.5 m.g.d. and this was gradually increased in amount until by the end of May a flow of 48 m.g.d. was being treated. By starting with a small volume of sewage it was possible to produce good activated sludge in eight days and thereafter to increase the flow with persistent production of a good effluent. At the time of the author's visit in July the plant was discharging a highly nitrified effluent (containing 20 p.p.m. nitrates and less than 5 p.p.m. albuminoid nitrogen) which was very clear and contained practically no suspended solids.

The Mogden plant covers an area of about 45 acres and at present serves more than 1,000,000 people. About 144 m.g.d. of sewage can be completely treated in the plant, and the remainder of the possible 690 m.g.d. wet weather flow, for which the sewers are designed, will be treated by settling only. On entering the plant the sewage passes through bar screens spaced 4 in. apart to remove coarse floating material.

TABLE I — OPERATING RESULTS (IN P.P.M.) OBTAINED AT WAKEFIELD USING COMBINED BIO-AERATION AND TRICKLING FILTER TREATMENT

	Abnormal sewage					Normal sewage					Weak sewage				
	Sus. solids	Oxygen absorbed	pH	Free NH_3	NO_3	Sus. solids	Oxygen absorbed	pH	Free NH_3	NO_3	Sus. solids	Oxygen absorbed	pH	Free NH_3	NO_3
Crude sewage	842	157.6	8.0	25	0	390	86.4	7.5	17	0	172	55.2	7.7	21	0
Settling tank effluent	222	67.2	8.4	20	0	140	49.6	8.4	14	0	84	30.4	8.0	15	0
Aer. tank effluent	32	23.2	7.7	16	tr.	32	20.8	7.8	13	tr	24	17.6	7.5	13	tr.
Filter effluent	20	16.8	7.0	5	8	18	12.0	7.4	7	8	18	15.2	7.2	7.5	8

TABLE II — AVERAGE OXYGEN CONSUMED VALUES (IN P.P.M.) BEFORE AND AFTER ADOPTING THE "SPLIT AND RETURN" SYSTEM AT ROTHERHAM

	1934	1935	Jan.–June 1936
Raw Sewage	81.2	90.1	82.3
Bio-aeration Effluent	11.2	8.0	8.0
Filter Effluent	11.6	10.2	13.4
Outfall	13.5	9.0	8.6
Percent Purification	83.5	90	89

These racks are followed by ¾ in. upright screens provided with brushes, which deliver the screenings to a belt conveyor leading to a comminutor. After maceration the fine screenings are returned to the incoming sewage, and no difficulty is experienced with settling the disintegrated material.

The screened sewage next passes into grit-chambers, equipped at their outlets with standing wave venturi flumes (Fig. 3A). These not only record the flow but also control the sewage level in the chambers in such a way that by means of a special (hyperbolic) cross section given to the channel, a velocity of one ft. per sec. is maintained at all flows. The length of each grit-chamber is 90 ft., giving a detention period of 1½ min.

Grit is removed by suction dredging and washed in a device developed by the engineer in charge. The accompanying diagrammatic sketch (Fig. 2) shows its essential features. After being washed, for about 1¼ hr., the cleaned grit is removed through the same pipe that supplies the wash water. Settled sewage or final effluent can be used for wash water. The organic matter in the washed grit amounts to about 5 per cent, but under poor operating conditions may be as high as 10 per cent.

Sewage up to a rate of three times the dry-weather flow is subjected to two stages of sedimentation. The primary settling tanks, eight in number, are circular with a diameter of 95 ft.; they are twelve ft. deep and provide a two-hr. period of detention (Fig. 3B). Deposited sludge is removed by a row of blade scrapers suspended from a revolving bridge (Fig. 3C) to a central well from where it is discharged into the sludge pumping main. The secondary tanks (four rectangular units each 200x150x12 ft.) provide for the removal of the lighter suspended solids during a four-hour detention period. They are equipped with the Mieder-type of sludge-removing mechanism (Fig. 3D). The general design applying to these tanks has been used for the storm-water settling unit. All tanks are provided with grease skimming devices.

Aeration tanks

The settled sewage is treated in aeration tanks, one battery of which is provided with longitudinal ridge and furrows with three rows of diffusers spaced at five-foot centers, while the other battery is arranged for spiral flow. Aeration is maintained for eight to twelve hours with an average compressed air consumption of 1.4 cu. ft. per gal. The suspended solids in the mixed liquor is kept rather high, amounting to 3,000 p.p.m., when returning 50 per cent of sludge by volume. The sewage flow and air passed to each tank is measured, although at present air and power consumption is considered of little consequence so far as costs are concerned because sludge gas is used for power production.

Final sedimentation

Final sedimentation of the mixed liquor is carried out in a battery of 40 settling tanks, each with a diameter of 60 ft., whose design combines features of the Dortmund type tank and the Dorr clarifier. These tanks have a straight side wall depth of eight feet, followed by a sloping pit 17 ft. in depth. The slopes incline at 30 deg. and are equipped with an electrically-operated rotating ring type scraping mechanism. Sludge is moved by suspended wooden scraper blades resting against, and parallel to, the slopes; an additional blade scrapes the side walls, so that no greasy or decomposing layers of sludge can accumulate.

The effluent from the Mogden plant is so highly clarified and stabilized that upon discharge into the Thames it forms a black pool in the midst of the more or less opaque river water. This creates the impression that the effluent is insufficiently purified, rather than that the river water is turbid and dirty.

Sludge digestion facilities

The sludge from the primary and secondary tanks is added to the surplus activated sludge and the mixture contains about four per cent solids. This mixture is thickened in two so-called "picket fence" thickeners, to about six per cent solids. The sludge is then pumped to the primary digesters —a total of twelve 70 ft. dia. tanks each 32 ft. deep, built in clusters of four and interconnected with galleries and piping. Eight of the tanks are equipped with floating gas tanks and stirring mechanisms, while four tanks have fixed roofs. All tanks are heated and provide sufficient capacity for a digestion period of fourteen days.

Gas production will be about one cu. ft. per capita, produced from sewage sludge that is mainly domestic, and containing about 25 per cent ash. The piping system in the primary digestion tanks although complicated permits considerable flexibility in operation. Individual temperature and gas measuring devices make it possible to determine variation in the different tanks, while a master gas meter shows the total quantities of gas produced. After this initial digestion, the sludge is pumped seven miles away to ten final digestion tanks and eventually dried on sand beds.

The symmetrical and compact design of the Mogden works is a credit to the designing engineers, and is in striking contrast to a number of the older English plants which have a sprawling appearance. The high earth walls surrounding the plant have already been sodded and with appropriate planting of shrubbery and trees this plant will be a show place for interested visitors.

General impressions

Problems which have received particular attention in England during the last few years are concerned with odor control, the performance of activated sludge, bioaeration, and trickling filter systems, better handling of sewage containing large quantities of trade wastes, extraction of greases, and mechanical removal of settled sludges. Important contributions are being made in these fields. The large number of treatment plants under control of drainage district authorities and the Ministry of Health, the keen interest of the sewage works managers, and the need for improvement and enlargement at many places are stimulating the development of more effective treatment methods and new devices. These notes should be considered, therefore, as indicative of some phases of progress rather than as a complete picture of newer practice.

The courtesies extended to the author by Messrs. Garner, Leach, Kershaw, Loach, Lovett, Townsend and Lockett, officials connected with the supervision or operation of sewage disposal plants, made it possible to obtain first-hand information for preparation of this article. Their interest and friendliness are greatly appreciated.

THE TENNESSEE VALLEY EXPERIMENT—II

Water Conservation and Flood Control

To save wasted flow for summer supply and to prevent destructive floods of the Tennessee the engineers had to forecast water supply variations, compare different regulation plans, and decide on best storage.

WHEN the Tennessee Valley Authority took up its many-sided assignment three years ago, it found that back of all its work on the river was the problem of conserving water and regulating the variable flow of the river most effectively. In every detail its work of planning and constructing improvements had to be fitted to the solution of this problem.

Before such a solution could be arrived at, however, fundamental data had to be restudied, including variation of river-flow, size of maximum possible flood, channel conditions, physical features of reservoir sites, effect of seasonal and annual variations on navigation and power possibilities, cost and value of storage, and related factors. Many of the necessary data were incomplete or lacking, and had to be obtained by lengthy investigation. Surveys of reservoir areas, examination of forests, and soil erosion as they affect silting, and relocation of the people residing in reservoir areas, required attention.

These studies soon became the key element of the TVA work, underlying most of its operations. Their water phases are described in brief outline in the present article.

Engineering studies delayed

Congress in initiating the TVA undertaking, (ENR Dec. 3, 1936, p. 771) had placed certain specific activities first on the Authority's program. Its instructions, together with the unemployment situation, required that the work of building a storage dam at Cove Creek on the Clinch River, known from prior investigations to be a desirable element of Tennessee River control, be started with the least possible delay. Other mandatory operations were involved in taking over Wilson Dam and preparing to market its power. Within a few months also, an increasing demand for quick reemployment led to orders to start on Tennessee River Dam No. 3 (Wheeler). Under such circumstances engineering studies could not claim first attention.

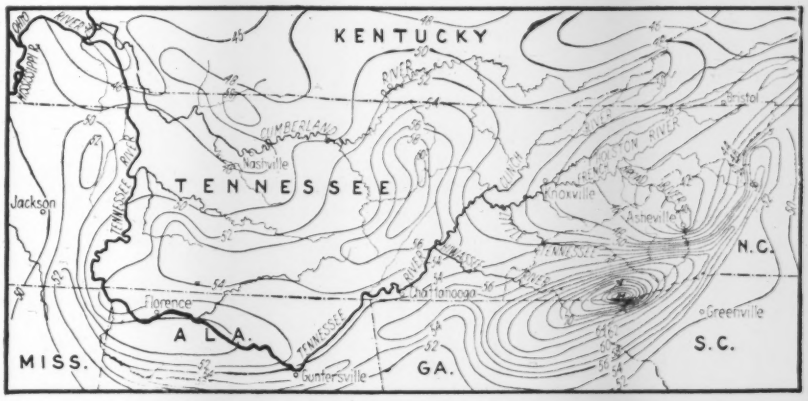


FIG. 1—HEAVIEST RAINFALL in the Tennessee basin occurs in the eastern mountain areas, which are the source of the largest floods and also contain the most valuable reservoir sites. Rain gages established by the TVA in the high mountains of the eastern part of the basin indicate that the area of high rainfall may be considerably more extensive.

Fortunately the urgent field work did not have to wait on full engineering data. Both Cove Creek Dam (Norris) and a complete chain of main-river dams including Dam No. 3 (Wheeler) had been studied by the army engineers as part of the investigation directed by House Resolution 308, and the data at hand were sufficient for re-study of the army designs in the light of the TVA's broader objectives. Preparations for construction were therefore begun at once, and separately from this work the technical studies were taken up.

Drainage areas and reservoir sites were surveyed, streamflow was measured, river records were assembled, borings were made at dam sites, and the cost and effect of various storages was analyzed. Special attention was given to storms and flood possibilities. As rapidly as conclusions could be drawn from these studies, plans for river development were worked out and compared. Progressively the flow studies became the controlling elements of the planning.

Even the initial construction work was affected by the hydrologic studies, for the plans of both Norris and Wheeler dams were modified to fit their results. In the case of Norris Dam the designs on which the army engineers were working had not yet reached the stage of exact determination of final height of dam. The TVA studies indicated the need for large storage, and the dam was therefore increased in height over that presented in the tentative design.

For other reasons Wheeler Dam was raised 5 ft. in height. This dam, standing at the head of Wilson Dam pool and itself creating a pool that would extend upstream to the foot of the next dam in the series, appeared to be committed as to height, by the height of the lock designed by the army engineers and nearing completion at the time the TVA came on the scene; but study of the structural design of the lock indicated that its walls were strong enough to permit of raising them a moderate amount. Operating studies showed that provision for both surcharge and drawdown was desirable, to give a storage range for flattening out flood peaks and to assure flexibility in adapting power output to probable variations in consumption. Since the elevation of lowest water was fixed by the necessity of carrying navigation depths up to the dam next above (Guntersville) the Wheeler crest had to be raised 5 ft. to permit of a drawdown of the same amount.

FIG. 2—FLOOD RUNOFF IS FAVORED by rugged topography in the headwater areas of the Tennessee.

From the beginning it was recognized that water conservation is not an isolated objective, since any storage of the excess flow of the high-water season will usually accomplish some flood control. Most water-regulating projects, therefore, serve more than one purpose and may be of greater value than that measured by any one use alone.

This fact influenced regulation plans because, in the final analysis, any program of water control must rest on economic justification; the cost must be less than the sum of all benefits. It also entered into the study of operating methods, since these must be worked out to minimize conflict of the several uses and secure greatest all-round effectiveness.

Accordingly the Tennessee River regulation studies, after assembly of all available information on the hydrologic and topographic conditions of the river, proceeded by considering the several effects of regulation jointly. However, it was soon found that the normally desirable amount of regulation could not give as much flood protection as was required at critical points, and therefore the subject of floods and feasible methods of protection also received independent further study.

Flow data

The Tennessee at its mouth has a mean annual discharge of 49 million acre-ft., almost equivalent to 2-ft. depth of runoff over the whole drainage basin. Due to the peculiar structure of the basin the larger part of this flow is derived from the upstream half.

Geologic investigations have shown that the upper part of the Tennessee River, which flows southwestward down the strike of the main valleys of the Appalachian system, ages ago continued in the same general direction to the Gulf. Later, changes in elevation of the earth's surface diverted the river from this course near Chattanooga, and forced it to flow westward through southern Tennessee and northern Alabama and thence northward through Tennessee and Kentucky to the Ohio River. The gorge of the Tennessee just below Chattanooga, where the river's drainage area is only 40 mi. wide, is a natural constriction that separates the upper and older part of the river's course from the lower; it divides the basin into two practically equal parts, of about 20,000 sq. mi. each. The two sub-basins differ in runoff characteristics.

Above Chattanooga the river meanders through rugged bluffs, developing a length of almost 200 mi. in an airline distance of 100 mi. In this length it receives five important tributaries, all draining mountain territory. The Clinch lies along the Cumberland Mountain front to the north; the Hiawassee, Little Tennessee, French Broad, and Holston, whose course cuts through the Great Smoky Mountains, drain the Blue Ridge on the south and east. High rainfall in this region, ranging to over 80 in. annually in certain areas, and the large runoff rates resulting from steep topography, contribute to large flood volume. In contrast, the lower basin has gentler topography, fewer tributaries, smaller rainfall and less intense storms.

For the river as a whole, which in its 652-mi. length falls about 500 ft. (an average fall of 0.77 ft. per mi.); the total annual runoff has a range from 15,000,000 acre-ft. to 51,000,000 acre-ft., corresponding to streamflows of 20,600 sec.-ft. and 70,300 sec.-ft. at Florence, Ala. The lowest daily flow that has been observed at Florence occurred in 1925; corrected for the regulating influence of the Wilson Dam reservoir it amounted to 4,070 sec.-ft., or 0.13 sec.-ft. per sq.mi. Larger proportional variations occur on the tributaries.

The seasonal flow variation of the Tennessee River is large. The flow at Florence ranges from a mean minimum of 10,800 sec.-ft. to a mean maximum of 257,000 sec.-ft. Complete seasonal equalization by carry-over from spring to fall would require a large storage volume than is economically feasible to provide. Equalization over a period of years, by supplementing the flow of low years through holdover from wet years, would call for still larger amounts of storage.

At this point the practical principle may be recalled that conservation and regulation must be proportioned according to costs and benefits. Not all streams are worth regulating, and not all reservoir sites can or should be utilized. On large rivers, also, uniform year-round flow cannot be obtained at reasonable cost, even where it is physically possible.

Multipurpose reservoirs

In the army study of the Tennessee River, completed in 1930, it had been found that a desirable degree of water control and water utilization could be obtained only by multiple-purpose reservoirs. The studies of the TVA confirmed this view. It happened also that calculations and comparisons of desirable amount of storage for different purposes led to substantially equal figures.

Eight years ago the Mississippi River Commission in its investigation of flood control on the Mississippi by reservoirs on the tributaries concluded that 10,000,000 acre-ft. of storage should be provided on the Tennessee. The TVA analyses of flood protection for Chattanooga and other communities on the Tennessee River indicated that local levee protection cannot provide for maximum floods unless these are reduced about 30 per cent by storage, and the amount of storage required for this purpose was found to approximate 10,000,000 acre-ft.—the same figure as computed from Mississippi River data. Separate calculations of the storages required on the tributaries to control flow in these led to individual volumes aggregating roughly the same figure.

Much less storage would be ade-

quate to provide for navigation for lockages and maintenance of desirable minimum flow in the completed project, with the river fully canalized by locked pools from its mouth to Knoxville; but the economics of the main-river dams would be interfered with by large reduction in power output both at the run-of-river plants and (because of reduced flow from the smaller storage) at the headwater reservoirs. The final conclusion emerged that the ultimate storage to be provided for in the comprehensive plan should be not less than 10,000,000 acre-ft. total, and that half or more of this amount should be held in reserve for flood-control storage in the headwaters.

Distribution of storage

The amount of storage on the main river obtained by a complete system of navigation dams (the final navigation project, as will be described in the next article, comprises nine dams, about 50 ft. high each, or seven in addition to the previously existing Wilson and Hales Bar dams) is about 4,000,000 acre-ft. in a 10-ft. range from 5-ft. surcharge to 5-ft. drawdown. Only part of this storage can be relied upon for flood control, however, because some of the dams would lose their surcharge effect by submergence in extreme floods unless these are greatly reduced by ample headwater storage.

Headwater storage projects that have been studied to the point of final adoption include Norris Dam on the Clinch River and a dam at Fowler Bend on the Hiwassee River. Fontana Dam, on the Little Tennessee, has also been studied fully and has been adopted by the TVA, but has not yet been approved by Congress. Norris, controlling a drainage area of 2,950 sq. mi., provides 2,600,000 acre-ft. of usable capacity up to top of crest gates, of which 1,500,000 are available for river regulation and power while 1,100,000 are specifically reserved for flood control; with additional storage above dam crest its flood-control capacity reaches 1,400,000 acre-ft. Hiwassee Dam, controlling 977 sq.mi., will have 400,000 acre-ft. of usable capacity, of which 230,000 acre-ft. will be reserved for flood control.

It should be added that the value of these reservoirs extends beyond flow equalization. By retaining silt they reduce deposition in the upper ends of the navigation pools. By lowering flood stages at these points they increase the length of time during which navigation can proceed and decrease the range of water level at navigation terminals. By increasing the low-water flow they raise the backwater at the heads of pools, thereby decreasing the amount of dredging in the downstream approaches to the locks. Finally, by reducing the floodflow in the main river they make the main-river pools more effective in retarding the advance of the flood wave and thus reduce the chance of synchronism of Tennessee River floods with the flood peaks of the Ohio and Mississippi Rivers.

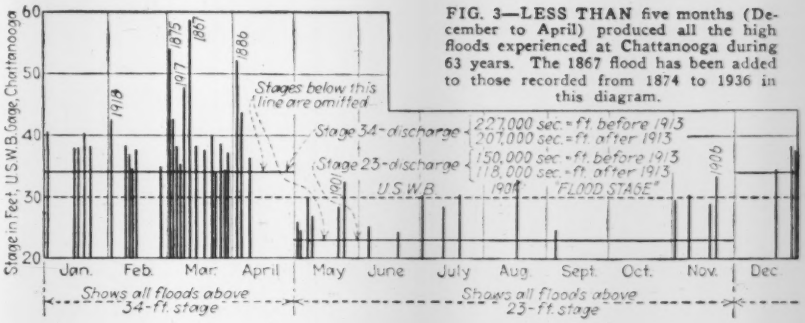


FIG. 3—LESS THAN five months (December to April) produced all the high floods experienced at Chattanooga during 63 years. The 1867 flood has been added to those recorded from 1874 to 1936 in this diagram.

Reservoir allocations

In developing the multiple-service storage design, the TVA engineers followed the principle that the flood-control reserve must not be encroached upon by other uses. Definite allocations of space for flood storage have therefore been made, and it is intended that these shall be strictly adhered to in operation. However, as the flood season in the Tennessee basin rarely ever extends beyond the period from Dec. 1 to about April 15, the flood reserve may in part be turned over to other uses as the end of this season approaches. In the case of Norris reservoir the designed flood-control allocation is that part of the reservoir above El. 1,020, which is bottom of spillway gates; above this level a storage height of 32 ft. (14 ft. gate height and 18 ft. surcharge) is possible, with a capacity of 1,400,000 acre-ft. Near the end of the flood season, however, part of this storage may be used for other purposes; that is, a flood that partly fills the flood-control reserve during the last days of the flood season may be in part retained for summer flow equalization.

There is always the risk, of course, that this reserve capacity may improperly be preempted for other use. Great floods occur only at long intervals, and the need of adequate flood reserve may be disregarded when a long period has elapsed without extreme floods. Thus the efficacy of the system depends on consistent and rigidly maintained operating principles.

Analysis of flood problem

The characteristics of the Tennessee River basin are such that floods of large magnitude may occur, and there is in fact a record of several disastrous floods. Unfortunately the period of precise record is much shorter than on many other large river systems—too short to warrant definite conclusions as to maximum future probabilities. Systematic records of flood stages were begun at Florence only in 1871, at Chattanooga in 1874, at Johnsonville in 1875, and at Knoxville in 1899. Newspaper accounts and other sources give only qualitative information on earlier floods. The lack of data is particularly serious because by far the greatest flood seems to have occurred in 1867, or nearly 70 years ago, and only rough estimates are available.

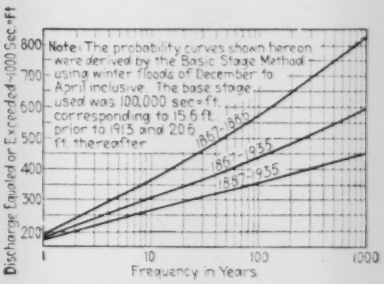


FIG. 4—FLOOD-FREQUENCY CURVES for Chattanooga differ widely according to the experience period on which they are based. By this method of calculation, in fact, a larger experience period may show less flood danger than a shorter period. If computed from 69 years of record, 1867–1935, the 500-year flood would appear to have a peak flow of 541,000 sec.-ft., while if computed from only 20 years, 1867–1886, it would be 610,000 sec.-ft. The frequency curve method was not considered to be dependable for flood planning.

It is definitely known that the river's flood problem is serious. The topography of the upper basin is rugged and all the tributaries here drain steep mountain areas of high rainfall; the ground surface is impervious and runoff is rapid and of high total percentage. At times even snowfall has contributed to floods, in spite of the southern latitude of the region. Finally, as the axis of this part of the basin is parallel to the normal path of winter storms, and the region is characteristically traversed by storms producing heavy general rains, a combination may produce a very great flood, especially when the ground is saturated by previous rains.

While the danger is less in the lower basin, the flood discharge from the upper basin may coincide with the runoff from a large secondary storm over the lower basin, so that severe floods are possible in this basin also. For these reasons flood protection has been a compelling consideration in the river planning from the start.

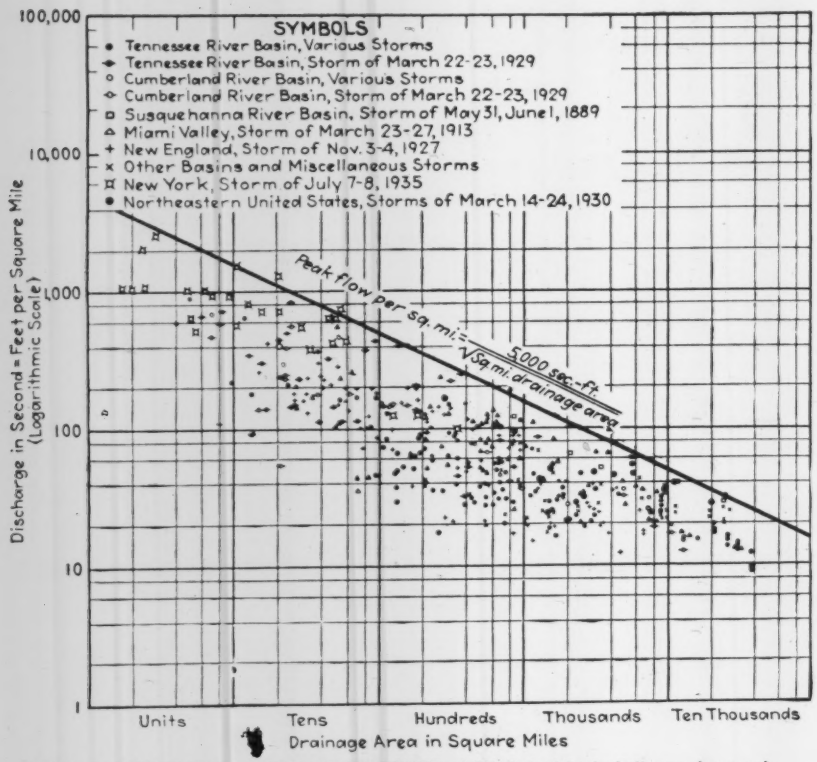

SYMBOLS
Tennessee River Basin, Various Storms
Tennessee River Basin, Storm of March 22-23, 1929
Cumberland River Basin, Various Storms
Cumberland River Basin, Storm of March 22-23, 1929
Susquehanna River Basin, Storm of May 31, June 1, 1889
Miami Valley, Storm of March 23-27, 1913
New England, Storm of Nov. 3-4, 1927
Other Basins and Miscellaneous Storms
New York, Storm of July 7-8, 1935
Northeastern United States, Storms of March 14-24, 1930
Peak flow per sq. mi. = 5000 sec.-ft. / √Sq. mi. drainage area
Discharge in Second-Feet per Square Mile (Logarithmic Scale)
100,000
10,000
1,000
100
10
1
Units
Tens
Hundreds
Thousands
Ten Thousands
Drainage Area in Square Miles

FIG. 5—COMBINED FLOOD EXPERIENCE of Mississippi basin indicates that maximum flood intensities in second-feet per square mile vary as the square root of the tributary area.

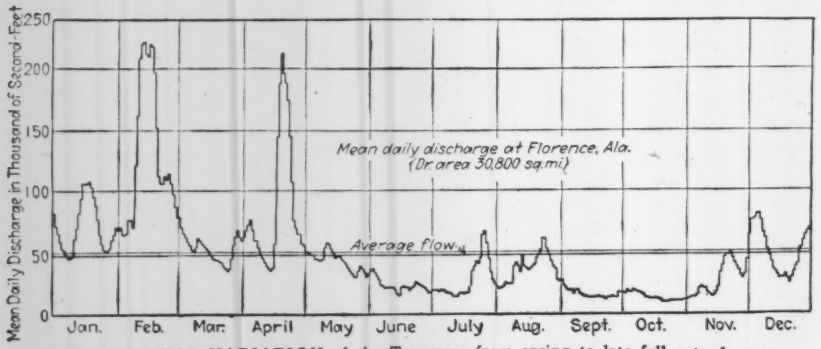


FIG. 6—ANNUAL VARIATION of the Tennessee from spring to late fall extends over a wide range, which means that large total storage is required for complete seasonal equalization. Equalization of wet and dry years would call for still larger storage.

Rainfall and streamflow records of the Tennessee area constitute the most important raw material from which to derive estimates of flood magnitudes. As the streamflow records are unusually short, much reliance must be placed on the longer rainfall records. Here, however, new uncertainties enter because the location of gages and other factors make it doubtful what any rainfall in any given sub-basin may have contributed to the riverflow. Rainfall records, however, permit comparison with other drainage areas. If the records show that two neighboring basins are closely similar in their rainfall characteristics, then it may be concluded that the storm responsible for an exceptional flood in one basin could occur in the other basin at some future time. Thus probabilities can be established not discoverable from the records of either stream basin.

Flood estimation

Because longer records of rainfall and flood are available abroad, many attempts have been made to use foreign records as a basis for formulas to represent the magnitude of flood that may be expected on any stream. However, in view of the many influences that affect flood magnitudes and frequencies the TVA engineers did not believe that much faith could be placed in flood formulas.

Study of the Tennessee Valley flood-control problem included the compilation of peak flood rates over an area in the eastern United States north and west of a line generally about 300 mi. inland from the seaboard but extending to the coast north of the Potomac River, and including most of the Mississippi River drainage basin. The results of this compilation are represented by the diagram Fig. 5. It demonstrates that maximum floods in this area approach a rather definite upper limit, defined by a line so related to the size of the individual drainage area under consideration that the magnitude of greatest flood expressed in second-feet of peak discharge per square mile of drainage area is inversely proportional to the square root of the area of the basin, $Q = 5000 / \sqrt{A}$. Floods of the so-called "cloudburst rainfall" type, which may affect very small streams, have no significance for the main Tennessee River, nor for the major parts of its principal tributaries, and are not included in the plotted record.

Consideration of these data in connection with the characteristics of the Tennessee River system led to the conclusion that a flood much greater than that of 1867 must be anticipated as a future possibility.

Chattanooga's flood hazard

It has long been recognized that the most critical point in the entire valley in respect to floods is Chattanooga. This city, with a population of more than 125,000, is so located that extensive residential areas and most of the industrial and business dictricts, which are built on low-lying ground, are inundated even in floods of moderate proportions. The depth of submergence in the flood of 1867 is shown in Fig. 8.

At this critical point the Tennessee River has a drainage area of 21,400 sq. mi. The 1867 flood, highest known, occurred before gagings were made, but discharge estimates from stage and water slope indicate that its peak flow was 459,000 or 21.5 sec.-ft. per sq. mi. In the light of the cumulative experience represented by the diagram Fig. 5, the conclusion is unavoidable that the drainage area of 21,000 sq. mi. may at times be subject to a peak flow of 34 sec.-ft. per sq. mi., which is nearly two-thirds more than the size of the 1867 flood. In other words, in place of 459,000 sec.-ft. a flood of 730,000 sec.-ft. can occur at Chattanooga.

As a matter of fact, a drainage area of comparable size (24,100 sq. mi.) that of the Susquehanna River at Harrisburg, Pa., experienced a peak flow of 31 sec.-ft. per sq. in. in March 1936, and previously had had a flood only six per cent lower (1889). The Susquehanna watershed is in many respects similar to that of the Tennessee; but the latter has even steeper slopes and higher rainfall rates, so that the Tennessee might be expected to have extreme floods even greater than those of the Susquehanna.

Various efforts were made to apply to the Chattanooga problem different methods that have been proposed for determining the magnitude and frequency of floods. Frequency curves were calculated by the basic-stage method, for example. These showed that if the studies were made as of 1886, covering all data for the period from 1867 to 1886, inclusive, the result would indicate a 500-year flood of 610,000 sec.-ft. If, however, by chance there had been no records previous to 1887, and a frequency study had been carried out for the 49-year period from 1887 to 1935, inclusive, the size of the 500-year flood would have been determined as 419,000 sec.-ft. peak flow. Again, using the total period from 1867 to 1935, inclusive, or 69 years, the frequency method would indicate 541,000 sec.-ft. Fig. 4, showing these three frequency curves, brings out forcibly that computations of this kind cannot be based on a short record—even one of 70 years—and that a wider range of data must be brought to bear on the problem. This is possible only by the cumulative data method of Fig. 5.

FIG. 8—THE HIGH WATER MARK of the 1867 flood, shown by the white arrow against the sign on the bank building at the right, indicates the extent to which the city would suffer in a similar flood. The industrial district is mainly lower than this business street.

Floods in the lower basin

Since the flood conditions represented by the peak discharges of Fig. 5 are generally those pertaining to an integral drainage area where all tributaries can cooperate and under unfavorable circumstances can synchronize, it was concluded in the TVA studies that they are not directly applicable to flood conditions below the Chattanooga-Bridgeport gorge. The differing characteristics of the two basins justify a smaller peak rate for the lower basin than the maximum indicated by Fig. 6. The adopted figure is represented by the formula $Q = 3500 / \sqrt{A}$. While the evidence supporting this formula is by no means strong, there is much less at stake than in the case of flood estimates for Chattanooga.

The total storage volume desired for flood control in the Ohio River and the lower Mississippi has already been noted as 10,000,000 acre-ft. For best protection of the Tennessee Valley the reservoirs should be on the tributaries and as low down on their course as possible. At least one reservoir on each of the five main tributaries above Chattanooga should be included in a protective system: Clinch River (Norris Dam provides this storage), Hiwassee (to be provided by Hiwassee dam), Little Tennessee, French Broad, and Holston. Until these storage reservoirs are definitely selected and decided upon, no final planning for local flood protection at Chattanooga will be possible. Tentative projects on the tributaries named will give an aggregate flood-control storage of about 3,000,000 acre-ft., or about two and a half times the flood storage available in Norris reservoir.

These projects, together with the three main-river dams required to extend navigation from Chattanooga upstream to Knoxville and Norris Dam, represent the maximum flood-storage from which Chattanooga can expect protection. For flood protection along the lower Ohio and Mississippi Rivers, the effect of the navigation dams in the main course of the Tennessee is also to be reckoned. Their equivalent of flood storage is placed at 3,000,000 acre-ft., making a total of 6,000,000 acre-ft. for the entire river. To bring this figure up to the desired 10,000,000 total for the Tennessee basin (from the standpoint of Mississippi River control) it will be necessary to construct additional storage on the tributaries.

Of the tributary reservoirs so far built or definitely planned, Norris reservoir provides the largest amount of flood storage (1,400,000 acre-ft., together with additional volume that can be provided by drawing the pool down below spillway crest in the early part of the flood stage). This volume is sufficiently large to permit witholding most of the flood flow completely until the flood crest has passed, and then discharging it at moderate rate. Inasmuch as the drainage area above the dam, nearly 3,000 sq. mi., is one-seventh of the total drainage area above Chattanooga, its flood-reducing effect at the latter point is obviously large. This effect received a striking practical demonstration in the spring floods of 1936, when the detention of flood waters at Norris reduced the Chattanooga stage by 3 ft.

The Hiwassee project will control a drainage area of nearly 1,000 sq. mi., and bring the total control above Chattanooga to one-fifth the area. Further control, however, is required on the other main tributaries above Chattanooga both for local protection and for flood control throughout the course of the Tennessee.

The sum total of the reservoir analyses was the conclusion that storage, while it will reduce flood peaks and the frequency of flood hazard at the river communities, cannot remove the chance of damaging floods at all points. The fact that levees and perhaps other flood-protective measures will be required at Chattanooga has already been mentioned. Similar local works will be required at a number of other towns.

Study of the problems of water conservation and flood control are carried on by the planning department, a subdivision of the Engineering Department of the TVA. Sherman M. Woodward, formerly of the University of Iowa, directs the work as chief water-control planning engineer, assisted by A. S. Fry, in charge of engineering data, James S. Bowman, head planning engineer, J. H. Kimball and N. W. Bowden, principal hydraulic engineers. Problems of malaria control in connection with the reservoir layout and operation were worked out jointly by the engineering department and the sanitary division. For the latter Dr. E. L. Bishop and W. G. Stronquist were particularly concerned with the problem. The critical nature of the Chattanooga flood problem led to submitting the planning department's data and conclusions to a special consulting board, composed of Gerard H. Matthes, principal engineer of the Mississippi River at Vicksburg, Ivan E. Houk, of the Bureau of Reclamation at Denver, Harrison P. Eddy, consulting engineer of Boston, and Daniel W. Mead, consulting engineer of Madison, Wis.

The third article in this series will appear next week.

Determining Beam Deflections Without Integrating

Considering simple beam as divided into two fixed cantilevers simplifies an otherwise difficult calculation

By Odd Albert
East Orange, N. J.

THE DEFLECTIONS of the free end of a fixed cantilever beam under various types of loading furnish the basis for a simple method of determining the deflections of freely-supported beams. Only a few fundamental formulas are necessary and with them the deflections may be figured without the use of complicated integrations.

The derivation of these formulas is based upon the discoveries by Mohr that: (1) the deflection angle at the free end of a fixed cantilever beam equals the area of the M/EI diagram; and (2) the total deflection of the free end of a fixed cantilever beam equals the statical moment of the M/EI diagram with reference to the free end. In accordance with these rules the formulas in Fig. 1 have been derived for the deflection of the free end of a fixed cantilever beam for a few common loading conditions.

The author first considered using the cantilever deflections instead of the elastic lines to determine deflections and moments when a student in Sweden some 20 years ago. Prof. Per Gullander found the idea new and assisted in developing it. However, at about that time Ostenfelt's slope deflection theory became known and, since this was a modification of the cantilever deflection idea, Prof. Gullander advised dropping the matter. Recently the old notes were recalled and, since the author had not seen the method published, were rewritten as given here.

The method is based upon the various deflections of the free end of a member considered as a fully restrained cantilever beam with all the direct loads applied and the influences of all other members in the system considered as loads. Thus, a direct load will tend to bend the free end down, and an imaginary reaction at the free end will tend to bend this end up. A moment at the free end will bend it up or down, according to its direction.

The method in general

If the deflection is required for a beam LR (Fig. 2 left) at the point C, the procedure is to consider this beam as two cantilever beams, LC and RC, fixed at C, and determine the deflections of supports L and R. At point C there will be a deflection angle t, equivalent to a deflection up of tx for part LC. The loading causes a deflection down (Eq. 3), and the reaction at L causes a deflection up (Eq. 1). These three movements must equal the deflection at C.

The part RC is treated similarly, except that the angle t is equivalent to a movement down of $t(s-x)$. The three movements of this part of the beam must also equal the deflection at C. Finally, if the beam is considered as a part of a structure, there will also be moments at L and R, causing movements of the respective ends as given by Eq. 5.

In cases where only the maximum deflection needs to be determined, the procedure will be somewhat simplified, since the deflection angle t for this condition must equal zero.

The following three examples illustrate the applications of the method.

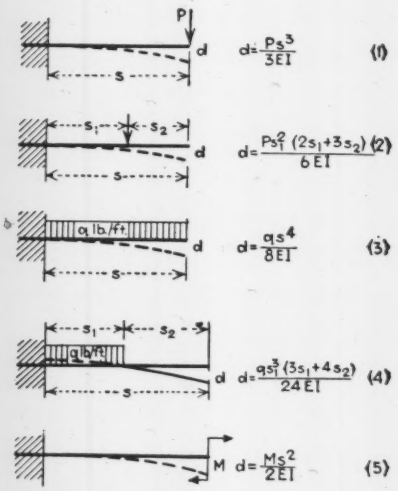
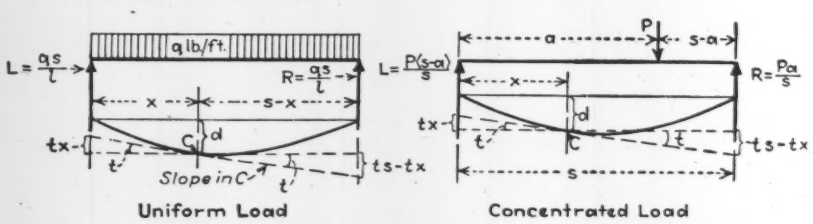


Fig. 1—End deflections of a cantilever beam under various types of loads.

Fig. 2—Simple beam deflection at point C determined from deflections of two imaginary cantilevers, RC and LC, for a uniform and a single concentrated load.



To determine the deflection at a point C (Fig. 2, left) on a simply-supported beam with uniformly distributed load, assume two cantilever beams, LC and RC, fixed at C.

For part LC,

$$d = \frac{qs}{2}\frac{x^3}{3EI} - \frac{qx^4}{8EI} + tx \qquad (6)$$

where the first expression is the upward deflection of end L from the reaction $qs/2$, and the second expression is the downward deflection from the uniform load q. The slope causes a deflection up of tx.

For part CR,

$$d = \frac{qs}{2}\frac{(s-x)^3}{3EI} - \frac{q(s-x)^4}{8EI} - ts + tx \qquad (7)$$

Equating equations (6) and (7) gives the general expression for the angle as

$$t = \frac{qs^3}{24EI} + \frac{qx^3}{6EI} - \frac{qsx^2}{4EI} \qquad (8)$$

This expression substituted in Eq. 6 gives the general equation for the deflection at any point:

$$d = \frac{qx}{24EI}(s^3 + x^3 - 2sx^2) \qquad (9)$$

In the special case where the deflection at the center of the beam is desired, $x = s/2$ and $t = o$, so that

$$d = \frac{5qs^4}{384EI} \qquad (10)$$

Concentrated load example

To determine the deflection at point C (Fig. 2, right) on a simply-supported beam with one concentrated load, assume as before two cantilever beams, LC and RC, fixed at C.

For part LC.

$$d = \left(\frac{p(s-a)}{s}\right)\left(\frac{x^3}{3EI}\right) + tx \qquad (11)$$

in which the first expression represents the upward deflection from the reaction at L (Eq. 1), while the second expression is the upward deflection caused by the sloping angle t.

Similarly, for part RC,

$$d = \frac{Pa}{s}\frac{(s-x)^3}{3EI} - \frac{P(a-x)^3}{3EI} - \frac{P(a-x)^3(s-a)}{2EI} - ts + tx \qquad (12)$$

Equating equations (11) and (12) gives the general expression for the angle as

$$t = \frac{Pas}{3\,EI} + \frac{Pax^2}{2\,EIs} - \frac{Pa^2}{2\,EI} + \frac{Pa^3}{6\,EIs} - \frac{Px^2}{2\,EI} \qquad (13)$$

Substituting this expression for t in Eq. 11 gives the general equation for the deflection at any point to the left of P as

$$d = \frac{Px(s-a)}{6\,EIs}(2as - a^2 - x^2) \qquad (14)$$

For the special case when the load is applied at the center of the beam, the maximum deflection will also occur at the center. Since $a = s/2$ and $x = s/2$

$$d = \frac{Ps^3}{48\,EI} \qquad (15)$$

Point of Maximum Deflection:

When the point of maximum deflection is desired for a load at any point of a freely supported beam, the general expression for the sloping angle t (Eq. 13) may be used. The maximum deflection will occur when the deflection angle equals zero. Setting Eq. 13 equal to zero, the point of maximum deflection is found to be at

$$x = \sqrt{\frac{a(2s-a)}{3}} \qquad (16)$$

A special case occurs when the load is at the right support. For this arrangement $a = s$, and

$$x = \sqrt{\frac{a^2}{3}} = 0.577s \qquad (17)$$

or the point of maximum deflection is 0.0773 s to the right of the beam center. Therefore, no matter where a load may be placed on the beam, the point of maximum deflection cannot be more remote from the beam center than 0.0773 s.

Numerical solution

In order to illustrate the application of the method to an actual beam under combined loads, the example shown in Fig. 3 is presented. The beam is a 20-in. 65.4-lb. I carrying three concentrated loads as well as a uniform load over a part of the span. The problem is to calculate the maximum deflection.

The point of maximum deflection cannot be further away from the center than $0.0773 \times 30 = 2.319$ ft. Therefore, it is evident that the point of maximum deflection will occur between the center and the 9,000-lb. load. Under the assumption of two cantilever beams, LC and RC, fixed at C, the bending line of the beam will be horizontal at this point and therefore $t = 0$, and this will be the point of maximum deflection.

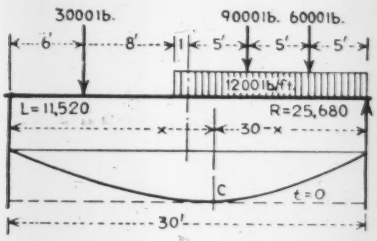


Fig. 3—Combinations of uniform and concentrated loads produce deflections easily determined by the cantilever deflection method.

Deflection at support L for part LC:

(a) from reaction L = 11,520 lb.; direction is up. Use Eq. (1)

$$d_a = \frac{11{,}520\,x^3}{3\,EI} \qquad (18)$$

and

$$EI\,d_a = 3{,}840\,x^3 \qquad (19)$$

(b) from load P = 3,000 lb.; direction is down. Use Eq. (2)

$$-d_b = \frac{1}{6\,EI} \times 3{,}000(x-6)^2 \times [2\,(x-6) + 3 \times 6] \qquad (20)$$

and

$$-EI\,d_b = 1{,}000\,x^3 - 9{,}000\,x^2 + 108{,}000 \qquad (21)$$

(c) from uniform load q = 1,200 lb. per ft.; direction down. Use Eq. (4)

$$-d_c = \frac{1}{24\,EI} \times 1{,}200\,(x-14)^2 \times [3\,(x-14) + 4 \times 14] \qquad (22)$$

and

$$-EI\,d_c = 150x^4 - 5{,}600\,x^3 + 58{,}800\,x^2 - 1{,}920{,}800 \qquad (23)$$

Since the total of these three deflections must equal d,

$$-150\,x^4 + 8{,}440\,x^3 - 49{,}800\,x^2 + 1{,}812{,}800 = d\,EI \qquad (24)$$

Deflection at support R for part RC:

(a) from reaction R = 25,680 lb.; direction is up. Use Eq. (1)

$$d_a = \frac{25{,}680\,(30-x)^3}{3\,EI} \qquad (25)$$

and

$$EI\,d_a = 231{,}120{,}000 - 23{,}112{,}000\,x + 770{,}400\,x^2 - 8{,}560\,x^3 \qquad (26)$$

(b) from load P = 6,000 lb.; direction down. Use Eq. (2)

$$-d_b = \frac{1}{6\,EI} \times 6{,}000\,(25-x)^2 \times [2\,(25-x) + 3 \times 5] \qquad (27)$$

and

$$-EI\,d_b = 40{,}625{,}000 - 4{,}500{,}000\,x + 165{,}000\,x^2 - 2{,}000\,x^3 \qquad (28)$$

(c) from load P = 9,000 lb.; direction down. Use Eq. (2)

$$-d_a = \frac{1}{6\,EI} \times 9{,}000\,(20-x)^2 \times [2\,(20-x) + 3 \times 10] \qquad (29)$$

and

$$-EI\,d_a = 42{,}000{,}000 - 540{,}000\,x + 225{,}000\,x^2 - 3{,}000\,x^3 \qquad (30)$$

(d) from uniform load, q = 1,200 lb. per ft.; direction down. Use Eq. (3)

$$-d_a = \frac{1{,}200\,(30-x)^4}{8\,EI} \qquad (31)$$

and

$$-EI\,d_a = 121{,}500{,}000 - 16{,}200{,}000\,x + 810{,}000\,x^2 - 18{,}000\,x^3 + 150\,x^4 \qquad (32)$$

Since the total of these four deflections must equal d:

$$-150\,x^4 + 14{,}440\,x^3 - 429{,}600\,x^2 + 2{,}988{,}000\,x + 26{,}995{,}000 = d\,EI \qquad (33)$$

Equating (24) and (33)

$$x^3 - 63.3\,x^2 + 498\,x = -4{,}197.03 \qquad (34)$$

which is the equation of the slope of the elastic curve between x = 14 and x = 20. Solving, x = 16.07 s.

Substituting this value of x in Eq. 23, and remembering that x is in ft., while E is in lb. per in.^{2} and I in in.^{4}, which means that the product EI (1,169.5 × 30,000,000) must be divided by 12^2 = 1,724, giving a value of 20,303,818, the maximum deflection is found to be d = 0.688 in.

It is to be noted that to solve this problem by such an ordinary method as the use of the differential equation for the elastic line, would have required five differential equations, each to be integrated twice. A total of 10 constants would thus have to be found. By the method of cantilever deflections all integrations are eliminated.

Boulder Dam Power Line Work to Start Soon

CONSTRUCTION of facilities for bringing Boulder Dam power into the Southern California Edison Co.'s system will be started early in the year, and will be completed by July 1, 1938. The company will build a 230,000-volt, 165,000-kw. line from Boulder Canyon to the company's Chino receiving station, a distance of about 238 miles. It will also be necessary to install additional equipment at the Chino receiving station, including transformers, a 50,000-kw. condenser for voltage regulation, and a high-voltage switch rack. Construction of the line and installation of station equipment will require an expenditure of about $3,750,000. This will be the second Boulder Dam power line, the first, owned by the bureau of power and light of the city of Los Angeles having gone into service on Oct. 7.

CURRENT HIGHWAY PROBLEMS—XI

Express Highways

Prospective highway transport points to the need of several thousand miles of intra- and inter-state general express rural highways

John S. Worley
Professor of Transportation Engineering, University of Michigan, Ann Arbor, Mich.

AMERICA has been too busy building travelable highways to consider very seriously the building of different highways for different classes of travel. As we progress however the idea is emerging and in the minds of many transportation students has reached the goal of positive pronouncement. A few weeks ago (ENR Nov. 12) in this series of articles E. C. Lawton pointed out the warrant for intercity arterial roads and indicated their requirements. In the article that follows Professor John S. Worley goes a step farther and reasserts his claim of the justification for long-distance express highways. —EDITOR.

A CAREFUL STUDY of our motor - vehicle transportation system reveals that it is rendering two distinct types of service, a neighborhood service of short distances, and a long-distance service between points far apart. Our motor vehicles during the last decade have been improved mechanically to such a degree as to make them quite capable of traveling over long distances at high rates of speed with a high factor of safety and economical cost of operation. They are, as a rule, required to operate over highways which have not kept pace with the improvement in the vehicle. These highways do not provide complete safety of operation, and do not permit the full benefit of the very efficient vehicle which we now have at our disposal. It is true that occasionally a short stretch of well-designed, well-located highway may be encountered but wherever available it will prove to be only a small fraction of the road that one has to travel when going long distances. There seems to be no question but that our present highways, in a very large degree and in a very large amount, are entirely inadequate for the service which people demand for long-distance highway transportation and which the present vehicle is entirely adequate to supply. This is particularly true with reference to passenger transportation and in a less degree to the small amount of long-distance goods transportation.

In every state there is a crying demand and need for the construction of highways which will permit safe and rapid movement of motor vehicles over long distances. The mileage needed of these roads is not great; a few well-located highways would provide for a major part of the distance to be traveled, leaving a small percentage of a trip at the terminals to be made over one of the existing neighborhood roads.

A specific example

In Michigan, in the Lower Peninsula, a single road across the southern end of the state from Detroit to Lake Michigan and Chicago, located on a line some ten or fifteen miles south of the cities of Ann Arbor, Jackson, Battle Creek, and Kalamazoo; another northwest from Detroit, passing eight or ten miles west of Flint, Saginaw, and Bay City, and then northwest again to a point just southeast of Houghton Lake, thence to the Straits, and a similar road along the west side of the state, being ten miles west of Grand Rapids and passing south of Cadillac, to a junction point in the neighborhood of Houghton Lake, where it would join the main road to the Straits, would furnish all that would be needed in the southern Peninsula.

But in addition to state systems, we are confronted with the problem of interstate express rural highways. While they might be comprised in part by intrastate express roads, their location should be controlled primarily by the needs of interstate traffic. An example of such a road would be found in one extending across the northern parts of Ohio, Indiana and Illinois, and serving the large industrial communities such as Cleveland, Youngstown, Akron and Toledo, in Ohio, South Bend in Indiana and Chicago, with its suburbs in Illinois. One might expect to find a similar road west from Chicago as far as Omaha, and another southwest from Chicago to St. Louis and Kansas City. It can be readily seen that a similar highway from Boston through eastern Massachusetts, Connecticut, southern New York, New Jersey, eastern Pennsylvania, and Maryland to Washington would be of this character.

Periodically during the last two decades suggestions have been made that commercial vehicles should be prohibited from using the existing system of roads, this latter being reserved solely for private passenger cars. Since factories, warehouses, railway terminals, residences, farms and other places of business are located upon practically every mile of interurban highways and on almost every block of our cities, villages and towns, such a requirement would necessitate a complete set of duplicate highways, which is impracticable. In all probability the suggestion for express commercial highways was made with the intention that it would apply to our more densely traveled highways between large industrial centers or thickly inhabited communities. Accepting this as the real intent of the suggestion, we at once find that such proposed express rural highways for commercial vehicles would, in a large part, occupy the same general location as the express rural highways for all vehicles.

Physical characteristics

The characteristics of the location and design of this type of road would require a right-of-way of a probable width of 200 ft.; at least two separate twenty-foot strips of paving surface at the time of initial consideration, and grade separations at all railroads and principal highways. The right-of-way should be fenced along its entire length, with entrances and exits only at authorized points, and with no structures or businesses accessible to the right-of-way except those needed to service the passing vehicles and passengers. The alignment should be such that the curves would have a factor of safety approximating that of the tangents. The inclination of grades should be such that the slowest-moving vehicle would always be able to travel at speeds in excess of 20 miles per hour. The surface of the pavement should be as perfect as possible, having no inequalities that would become hazards to cars traveling at high speeds. The surfaces should also be of a quality to provide the maximum friction to prevent slipping or skidding. The visibility along the road, with reference to both grades and curvature, should be such that a motor car would be seen readily at a distance of 1,500 ft. Branch roads would connect with all towns.

As has been stated, the initial road should be provided with two separate 20-ft. strips of pavement to separate the traffic and eliminate all the hazards of two-way traffic on the same pavement. A 200-ft. right-of-way would provide ample space for widening the initial pavements as the traffic load demanded or for additional strips of pavement whereby the traffic could be segregated according to its class, making possible the complete separation of motor buses and motor trucks from private passenger cars.

Careful design needed

A highway of this kind should be located, designed and constructed with the best engineering talent available. Careful studies of subsoils should be made to insure no shrinkage or settlement that would affect the durability or quality of the paving surfaces. It is only recently that we have come to a realization of the importance of the proper subgrade for our highways. Extensive research should be made to determine the effect of all sizes of loads passing over various paving surfaces at varying speeds to determine the most durable and satisfactory material for pavements.

Extensive research also should be carried on in connection with highway signaling so that the best system could be devised and adopted, with an equal amount of research in signal lighting and lights required on moving vehicles at night. Research should be made into the behavior of drivers and occupants of cars so that, wherever possible, every element of danger will be eliminated in operating vehicles over a high-speed road of this kind. An extensive study should be made with reference to every element of the transportation system so that economical and adequate provision will be made at the time of construction for the traffic that the road will be required to carry during the next 25 or 30 years.

It is to be supposed that in a few instances topographical conditions would be encountered where some modifications would have to be made to the above general specifications. Instances of this would be in crossing mountain ranges, passing along streams located in narrow gorges or similar conditions.

Financing and operation

For those express rural highways available to all classes of motor vehicles that would be considered as intrastate or forming a part of an interstate system, it would appear that the original cost of construction and the annual maintenance might be provided under the existing plan for the construction and maintenance of state-highway systems. Where these general express highways are primarily of an interstate nature, it is reasonable to suppose that the federal government would provide a much larger share of their construction and maintenance than has been its practice in the construction of our state-highway systems.

When we come to consider express highways for the exclusive use of commercial vehicles, motor trucks and motor buses, the same financial scheme would appear as probably being acceptable.

Separate commercial highways

The suggestion for the construction of separate highways for commercial vehicles has frequently carried the proposal that the original cost of construction and maintenance be borne entirely by these commercial vehicles. A study of this proposal brings to light many serious difficulties. The question at once arises, would it be expected that the original cost of construction would be voluntarily contributed by the commercial vehicles which were to use these express highways and is there any practicable way to determine the proportional construction costs which should be allocated to each vehicle. This question is further complicated by the fact that the existing vehicles would use the road for only a short period of its life.

To meet this problem it has been suggested that these express commercial highways be operated on a toll basis. This would require that the federal and state governments provide the capital with which they are to be built, assessing a toll against each commercial vehicle which passes thereover in an amount the totals of which for the year would amount to the total annual cost of the road, being the cost of maintenance, operation and the use of the capital invested by the governments. These tolls in all probability would of necessity have to be quite high, in which case the commercial vehicles would not use the toll roads but would use toll-free roads that would parallel the toll roads.

To require commercial vehicles to use these roads under legal compulsion would at once create many difficulties. These express highways being limited in their course to large industrial centers and communities would make them available for only a small amount of the total commercial transportation in any state.

By charging tolls further complications would arise in our present scheme of motor-vehicle taxation, which is predicated upon the theory of a proper tax for each vehicle. Any scheme looking to the operation of express highways for commercial vehicles on a toll basis seems to contain almost insurmountable difficulties.

The operation of express rural highways which would be available to all types and classes of motor vehicles would appear to contain no serious problem. Their maintenance, repairs and policing would approximate that of our present state highway systems.

Express highways for the sole use of commercial vehicles would create no special problems in the maintenance and repairs but the policing would not be so simple. Just in the degree the use of these roads would be made compulsory would the policing difficulties increase. Were these commercial express highways toll-free, drivers of private passengers cars would immediately attempt to make use of them in every instance where it would appear to the driver some advantage would accrue to him. If they were made toll roads there would be no particular difficulty in operating such toll gates other than the additional expense.

Justification a question

Difficulty will be encountered in finding a definite and positive justification for the construction of either type of express rural highways. The elements that would enter into the justification are so numerous and so variable with respect to each individual project that no common standard or measurement can be given. Where there exists a single 20-ft. slab of concrete or other high grade surfacing material, well located, designed and constructed, all other conditions being equal, there would be much less justification for building an express highway than if no such road existed. Again, if this same existing road was old and must be rebuilt in the near future, then there would be more justification for building the express highway. Of course, the amount of the immediate and future traffic would have a great bearing upon the subject. Even the manner in which the project would be financed would be one of no small significance. Each project should be given thorough study, from which the responsible officials would form a judgment, which judgment at no time can be based upon some common standard.

When we consider the justification for building an express highway for the exclusive use of commercial vehicles, the problem becomes still more difficult. From the studies which we have made it would appear that outside of one or two highways of this kind, possibly being confined to one extending from New York to Philadelphia, a justification could probably not be established.

A survey of our present needs and a conservative estimate of the needs of the immediate future, would point to strong probability of the justification for building several thousand miles of intrastate and interstate general express rural highways. The responsibility for the study of this problem, planning, and its promotion should be primarily the duty of the Bureau of Public Roads, with the co-operation of the various state highway commissions.

CONTROL OF ROCK DUST IN CONSTRUCTION—III

Silicosis Legislation

IN THE LAST TWO ISSUES *we have presented articles on the medical aspects of silicosis and practical methods of dust control in rock drilling and excavation, written by Dr. A. J. Lanza and Theodore F. Hatch, outstanding authorities in the silicosis field. They pointed out that the health and medical aspects of silicosis are fairly well understood, and that silica rock dust, the sole cause of the disease, can be controlled by mechanical means. The following article closes this series on silicosis with a summary of the status of preventive and compensation legislation, the third phase of the silicosis problem.* —EDITOR.

FEW CONTRACTORS and other operators of rock drilling and excavation equipment realize the extent of their liability for silicosis under the law. If the various state occupational disease laws were definite or if their interpretation and application were somewhat uniform, the status of contractors' liability would be of simple determination. However, because of the wide divergence of the laws, their lack of uniformity, conflicting court decisions and the absence of either court rulings or acts in some states, the liability and compensation situation is confused.

In brief, this is the situation confronting contractors today in regard to the legal aspects of silicosis: A few states have specific and definite silicosis prevention and compensation acts. Others have vague and loose occupational disease compensation acts, under which silicosis may or may not be included, often depending upon court interpretation. In a third group of states silicosis liability has been read into the workmen's compensation acts by court decisions that regard the disease as an occupational accident; the situation illustrates the uncertainty of present silicosis legislation, for in the absence of specific acts it is possible that at any time a court may declare silicosis to be compensable under existing acts. Finally, the remaining states have no occupational-disease legislation whatever, but in most of them the right of common-law action for silicosis damage apparently exists, usually subject to some doubt because of absence of legal experience.

Summary of existing laws

According to a survey recently completed by the legal committee of the Air Hygiene Foundation, occupational diseases are compensable, to some extent at least, in the District of Columbia and sixteen states: California, Connecticut, Illinois, Kentucky, Massachusetts, Minnesota, Missouri, Nebraska, New Jersey, New York, North Carolina, North Dakota, Ohio, Rhode Island, West Virginia and Wisconsin. However, silicosis is not included among the compensable diseases in five of these states: Minnesota, Nebraska, New Jersey Ohio and Rhode Island. In West Virginia, silicosis is the only occupational disease made compensable.

Maryland, not included in the above list, is in a class by itself. Its courts have held that phosphorous poisoning, for example, resulting from exposure over a period of years, comes within the term "accidental injury" because the injury was suffered by chance, and found that the condition resulted from the negligence of the employer, and was therefore compensable, although the court held the poisoning was not an occupational disease. The result seems to be that in Maryland a diseased condition is compensable if caused by the negligence of the employer.

Common law liability

The common law liability for occupational disease was also of concern to the Foundation's legal committee, and was found to be difficult to determine with exactness. In many states there appears to have been no occasion for the courts to decide whether the right exists, at common law, to recover for occupational diseases due to the negligence of the employer. In other states, where the right did exist, it has been modified by passage of workmen's compensation acts. Courts in Illinois, Michigan, Ohio and North Dakota have held that no such common law right of recovery exists. In Connecticut, Georgia and Texas the common law right of recovery was found to be extremely doubtful.

The common law right to recover for occupational disease caused by the negligence of the employer probably exists, although there is some doubt, in twelve states: Delaware, Iowa, Maine, Maryland, Massachusetts, Oklahoma, Oregon, Pennsylvania, Rhode Island, Tennessee, Virginia and Washington.

That such right does exist seems well established in another group of twelve states: California, Kansas, Kentucky, Louisiana, Minnesota, Mississippi, Missouri, Nebraska, New Hampshire, New Jersey, New York and West Virginia. It should be noted, however, that occupational disease is compensable under compensation acts in all of this group except four: Kansas, Louisiana, Mississippi and New Hampshire.

In the remaining seventeen states and the District of Columbia no court decision on the right of recovery has been made. Again it should be noted that occupational disease is compensable in three of this group: District of Columbia, North Carolina and Wisconsin.

Details of laws

Following a study of the economic and legal aspects of dust diseases in industry, the U. S. Bureau of Mines published a summary and details of occupational disease compensation acts of many states, Canada and foreign countries (U. S. Bureau of Mines Information Circular 6,892—August, 1936). Much of the following concerning details of various acts is based on information contained in this circular.

New York's experience is interesting. Rules and regulations against dust hazards in industry have been promulgated by the Industrial Board since 1913, until today the factory hazards are generally under control. However, it was not until 1935 that the legislature passed an occupational disease compensation law, and then went the limit by including all such diseases as compensable under the workmen's compensation act. Consternation reigned. Insurance policies were cancelled by the wholesale. Employers were frantic in efforts to obtain coverage at premium rates other than at prohibitive levels.

Yet, despite the wide open invitation provided by the law, very few claims were filed. Because of accrued liability, however, insurance premiums on silicosis coverage were found to be so burdensome that a committee made up of employer, labor, and insurance, formulated what is now popularly known as the silicosis legislation of 1936. The occupational disease compensation act was amended, as far as silicosis was concerned, to limit compensation awards until an insurance experience could be built up; and furthermore made mandatory the use of approved dust-control equipment and methods on all rock-drilling apparatus. This law became effective on June 9 last and as yet no approval has been granted, though tests are now being made of various equipment. The man-

datory use of dust-control apparatus is found only in the New York law, and the creation of medical and engineering boards stamps the state as a leader in preventative legislation, not content with mere compensation after the injury has taken place.

Medical examination

Another peculiarity of the New York silicosis law, a point at variance with almost every other comparable act, is the discouragement of medical examination of workers, except, of course, those filing claims. The Industrial Commissioner regards medical examination undesirable because: "In the first place, from the standpoint of the cost of insurance, it makes the workers claim conscious, and more important still, it has a serious effect upon the morale of the men by exciting them about their physical condition. Then, too, if the men are ruthlessly discharged, they of course have recourse to civil action against their employers because of the physical impairment which arose in the course of their past employment. . . . Such a development would be unfortunate in its effects upon industry, employment and the morale and actual health of the workers. Physical examination of employees who have spent many years in an industry would be justified if there were some method of compensation for those who, while not disabled in the sense that they are unable to perform work, are found to be suffering from dust disease in some stage."

Under the West Virginia act, employers may elect to come within its provisions, and the employer who makes such election is not liable to respond to damage suits at common law or by statute. The West Virginia law provides that claim for compensation must be filed within one year from and after the date of the last injurious exposure to silica dust. The industrial commissioner promulgates rules and regulations concerning the act, and thereby may require medical examination of workmen.

The North Carolina act, applying to industries designated by the industrial board as being dangerously dusty, requires medical examination of all employees engaged or about to be engaged in an occupation regarded as exposing them to the hazards of silicosis and asbestosis. Re-examination at regular intervals is provided for. Compensation is variable; definite amounts are stipulated according to the stage of silicosis. Claimants for compensation must have worked at least two years within the state.

As regards dust-control equipment it is of interest to observe that a provision of the Illinois law making mandatory the use of dust-control equipment was declared unconstitutional by the state supreme court in 1935 on the ground that it violated the "due process" clause of the state and federal constitutions. The court held that the legislature had failed to set up any standards by which the judgment of the administrative department could be measured, and as a result the "department could decide arbitrarily what devices or methods approved are reasonably necessary, reasonable or adequate." The New York industrial department, it will be noted, is working to definite standards of performance, established by a committee, in testing equipment for possible approval.

Courts establish coverage

The compensation law of Massachusetts, in effect since 1912, was not regarded as covering injuries caused by inhalation of silica dust until a court decision made in 1929. Claims for compensation for silicosis, however, were rare until "claim consciousness" was aroused in 1933 by publicity given to the dismissal of 42 employees from a foundry because upon medical examination they had manifested incipient symptoms of silicosis or tuberculosis. Since then conditions in Massachusetts have been chaotic, to the distress of all parties concerned. Many employers are having difficulty in obtaining insurance because they are unable or unwilling to pay the price demanded by insurance carriers for silicosis coverage, whereas the insurance carriers are reluctant to provide such coverage at normal rates for fear that they will not prove adequate.

In Wisconsin, the workmen's compensation law covered only accidental injuries or injuries by accident until 1919, when it was amended to cover occupational diseases. Notwithstanding this amendment, claims for silicosis were almost negligible in Wisconsin until 1931, when unemployment became widespread and numerous claims were instituted. With data available for losses under policies expiring in 1933, there is now about three years' experience to indicate the results of applying the Wisconsin law to compensation of silicosis; and such experience is alarming.

Situation highly confused

The above surveys of legislation relative to occupational diseases, of which silicosis is one, reveals a highly confused situation. There are many reasons for such confusion. H. B. Meller, managing director of the Air Hygiene Foundation, points out that "Each state is a unit—a sovereign—and handles its problems in its own way. Uniformity is lacking, although of course the statutes of many states are similar. The courts of the various states follow such precedents as appeal to them; consequently, on any important question, there is likely to be a divergence of opinion among the courts, and often the courts fall into two or more groups, each group following a different theory with respect to the same legal problem."

Variety in interpretation by the courts is but one cause of confusion. Another is the wide range in application of many of the state occupational disease compensation acts. In some of them, especially the older ones, occupational diseases are included as compensable in the same manner as an injury, without definition as to just what constitutes an occupational disease. They do not definitely fix blame on any particular employer, and offer little or no protection as to limitations of claim in respect to time of employment. In other acts, occupational disease coverage has been read in by court decisions. In Massachusetts, for example, the compensation act by its terms has covered all injuries arising out of employment since 1912, but it was only in 1929 that the courts decided that a pulmonary disease of slow contraction constitutes such an injury, and it was not until several years later that events occurred to make the workers generally "claim wise."

In former years such laws worked fairly satisfactorily, for there was little disposition on the part of workers to claim compensation for disease except for one palpably caused by bad working conditions or patent neglect on the part of the employer. However, in the past five years or so, perhaps because of disturbed times, the number of occupational disease claims has greatly increased, accompanied in some instances by sensational treatment by the press, which further accentuated the rush of claims.

Difficulties in framing laws

Then, too, when the subject of occupational disease compensation is considered there is little wonder that the present situation is perplexing. Establishing a basis of compensation for injuries is fairly simple. The injury occurs at a certain time and place, under known employment conditions. Its severity and resulting disability are of definite determination. Experience has developed an expected cost upon which insurance premiums can be based.

Occupational diseases, such as silicosis, present a far different problem in compensation. Silicosis develops only after years of exposure to silica dust; the length of exposure necessary to produce the disease varies greatly with the concentration of dust to which the worker is exposed, the length of exposure, and the state of health of the individual. Often the worker has changed employers several times during development of the disease. How to determine which employer is responsible is a serious question. What constitutes disability is another ques-

tion. A workman may have silicosis in its first or even second stage, and yet not be handicapped in plying his trade. Or, having incurred silicosis and being threatened with disablement if he continues to be exposed to a dust hazard, he may be forced to change occupations, perhaps at some loss in earning power. How much compensation is he entitled to in this case? Silicosis alone does not always cause disability, but it does frequently predispose to tuberculosis. The latter is a fairly common disease. Who is to determine whether a certain individual contracting tuberculosis on top of a mild case of silicosis would not have become infected without the silicosis?

One of the most serious questions confronting those writing a new silicosis compensation law is the disposition of old cases. Are present silicotics entitled to compensation, and if so, who pays for it? If not, they are presumably entitled to recovery through civil law suits. In either event, industry pays heavily.

Dr. L. U. Gardner, of Saranac Laboratories sums up the situation as follows: "As to occupational diseases, and especially those of the progressive type and slow contraction, by reason of the indefiniteness as to time, place and disability, the problem is so complicated that it is difficult to avoid legislation that will not be retroactive in its effect. Insurance is a protection against future hazards. Industry cannot afford to pay for losses which have accrued, nor can the insurance companies afford to give coverage for past liabilities before the law became effective. No reservoirs have been created to meet the extra burden."

Need for compensation legislation

Compensation for occupational diseases, that is, for disability that actually arises out of the course of employment, is just as necessary as is that for accidents. For the worker it assures justice and some measure of recompense without recourse to civil law suits; for the employer it establishes an insurance against such suits and provides discharge of a financial obligation to injured employees at a moderate cost.

The usual unsatisfactory course of silicosis suits and the need for compensation legislation is pointed out by Theodore C. Waters, attorney of Baltimore, Md., who says:

"The usual form of declaration contains allegations that the defendant manufacturer caused the plaintiff to work in an atmosphere where silica dust existed; that the defendant knew or should have known that certain materials used by the defendant employer contained harmful or dangerous agencies of silica which were destructive to life and health in the human body; that the defendant was guilty of negligence in failing to warn the plaintiff of the danger and in failing to provide the plaintiff with a safe place in which to work or safe appliances with which to work; that thereby the silica became introduced into the plaintiff's lungs and body, causing him permanent injury.

"The defense pleadings set up the defense of assumption of risk by the plaintiff, the plaintiff's contributory negligence, the negligence of the plaintiff's fellow servants and a general denial of the allegations of negligence as charged by the plaintiff.

"It is needless for me to emphasize the seriousness of this type of litigation. Class is arrayed against class. The local press in those places where the cases are tried will carry sensational headlines with respect to the trial, describing the terror of the disease and emphasizing each complaint against the manufacturer. Suits are filed, not singly, but by the dozens. The whole community wherein the industrial plant is located becomes aroused, with the attendant industrial chaos, and by the time trial day arrives, every citizen of the community is so prejudiced against the defendant that it is almost impossible to procure an impartial trial.

"The ultimate solution of the problem of compensation for silicosis must be found in some type of legislation that will remove this dispute from the field of common law suits. In the same way that workmen's compensation acts eliminated such actions for accidental injuries, some legislation must be devised to eliminate such actions for occupational disease injuries.

"The honest employer desires to provide compensation for those injuries occurring to his employees as a result of the industrial processes in which the employee is engaged and which are peculiar thereto. The honest employee similarly desires compensation only when he has suffered actual injury."

Another view of the undesirability of having silicosis claims settled by common law is expressed by Frederick S. Kellogg, an attorney of Jersey City, N. J.: "Procedure under common law is not well adapted to determination of liability for silicosis. In a common law action it is necessary to establish three things: (a) Has the plaintiff contracted silicosis? This is almost purely a medical question. (b) If the plaintiff has contracted silicosis, did he contract it because of conditions in the defendant's plant? This is partly a medical and partly a non-medical question. Whether the conditions, having been once determined, were such that they probably caused the silicosis, is a medical question. (c) The remaining point to be proved by the plaintiff in a common law action is whether the defendant was negligent in permitting the conditions which caused the injury to the plaintiff by silicosis. This is a question of ordinary law [illegible] it involves practically no [illegible] questions.

"The employee's remedy by [illegible] law action is slow and difficu[illegible]. Such cases have to wait their turn on the court calendar and when they are reached, the trial frequently consumes from two to four weeks. The greater part of the time is consumed in the consideration of medical questions. The determination of these questions is left to a jury; the jury has no training in medical matters except that which it acquires during the trial. The common law procedure is extremely expensive, both to the employee and the employer. It is uncertain of arriving at a just result, and is not satisfactory to either party."

The ideal law

Obviously compensation legislation for occupational diseases is desirable. What should be the scope of such a law? What general provisions should it contain? What limitations and restrictions should it embody? The answer is given by the Association of Casualty and Surety Executives, representing the insurance companies that cover occupational disease risks, in an eight-point outline of a satisfactory compensation act.

1. A schedule of the diseases to be deemed "occupational diseases." Such schedule should include all those diseases, but only those diseases, to be found in the state, which, according to prevailing medical opinion, can be traced to origins in "trade-risks"—i.e., risks, not of ordinary life, but created by special practices or processes in industrial occupations.

2. A special regime for the expert adjudication of medical questions and for medical and engineering control for purposes of prevention.

3. Special provisions to require a definite period of exposure as a condition to the right to compensation for an occupational disease; to limit the time within which disability or death must follow exposure; and to exclude application to cases resulting from exposures entirely prior to the effective date of the compensation coverage.

4. Specification of an event from the date of which shall run the time limit for notice of injury and claim for compensation—in lieu of the "date of the accident," as under the typical compensation laws.

5. Provision for reduced compensation in cases of mere aggravation or acceleration of the consequences due to other diseases or infirmities.

6. Provision for special compensation to workmen laid off before actual disablement because of manifestation of first symptoms of an occupational disease—such a provision being especially essential in application to silicosis.

7. Provision for waivers of full compensation in special cases of silicosis and other diseases of like character, where disablement has not resulted.

8. Special limitations on the obligatory medical benefits in cases of silicosis and other diseases of like character.

Insurance authorities regard all of

the above points as highly essential, but stress particularly the first and third items. It is difficult enough, they point out, to cover the risk on the scheduled diseases without being subject to responsibility for any and all diseases that might be classed as occupational. They also regard any scheme of compensation that does not eliminate old cases or those resulting from exposure prior to assumption of the risk as ruinous to both industry and the insurance carriers.

Warning sounded

Warnings have been sounded by legal and insurance authorities against improper, vague and loose legislation concerning compensation for occupational diseases. These apply to acts already in effect as well as to proposed legislation. F. Robertson Jones, general manager of the Association of Casualty and Surety Executives, has campaigned vigorously for sane, adequate and equitable laws. One comment he makes: "The menace of silicosis is serious, but it is a mistake to concentrate attention upon it to the exclusion of a greater menace for industry—that is, the danger of having imposed on industry a liability for compensation, regardless of fault, for all diseases arising out of the employment, or for all occupational diseases undefined. In other words, the danger of liability for all common diseases contributed to, aggravated or accelerated by the customary activities or exposures incident to an occupation or for all common diseases which are more prevalent among workers in certain occupations than among workers in general. This latter liability is a menace to industry as a whole; whereas silicosis is a menace to only a relatively few industries."

Again, Mr. Jones says: "In my opinion, sound principles support the doctrine that the only diseases (other than diseases resulting from occupational accidents) for which industry owes compensation are those diseases which originate from risks created by industrial processes, as distinguished from the ordinary risks of life. What diseases may be so classified and practically diagnosed as such, is a medical question. The only practical way of determining that question is that which is now generally adopted but from which we, in America, have departed in spots and are being urged to depart generally, namely, of listing or 'scheduling' such diseases as the consensus of competent medical opinion determines to be traceable to strictly occupational risks. Of course, such a schedule can never be finally definitive. New occupational diseases will continually be created or discovered, which should be added to the schedule when the opinion prevailing among medical experts so dictates.

"Industry should not be obligated to compensate for the consequences of the ordinary diseases of life, congenital weaknesses, the infirmities of old-age, or, much less, of vices or bad habits, merely activated, aggravated or accelerated by the ordinary activities and exposures of work. The schedule plan of defining occupational diseases eliminates such obligation. But there remains a difficulty even under the 'schedule plan' in those cases where an occupational disease merely contributes to disability or death. This is a problem of great importance in connection with compensation for dust diseases of the lungs, such as silicosis. If elderly workmen retire or die from other causes but have traces of silica fibrosis in their lungs, should a diagnosis of silicosis as a contributory cause of disability or death obligate the employer for *full* compensation? Certainly, at the rates of compensation prevailing in this country, many industries could not stand the burden. In my opinion, it is necessary in such cases to apply some rule for reducing the compensation to the degree to which the occupational disease contributes to the acceleration of disability or death."

Cost of insurance

Mr. Jones goes on to point out the difficulty in compilation of cost of risk under the present confusion of some state laws. "A result of such divergent developments in our laws is that, now, in some states, employers are liable for compensation, regardless of fault, for injuries to health indefinitely, at the whim or fancy of industrial commissions or courts imbued with a progressive spirit of liberality; while in other states employers, besides being liable for compensation for accidents, or for accidents and many occupational diseases, are also liable in unlimited damages for all other injuries to health that sympathetic juries may choose to ascribe to their faults; whereas in yet other states, *e.g.*, Illinois, the law is in such chaos that there is no telling for what misfortunes of employees their employers may be held liable—whether in damages or in compensation. This affects insurance carriers as well as employers, and is the root of the difficulty that many establishments now encounter in obtaining insurance. How can insurance carriers fix reasonable rates for insurance when they cannot know what they are insuring against, or while the risk insured against is being enlarged by leaps and bounds, at odd intervals, by 'liberalizing' developments in the law? That the financial risk involved in insurance under such kaleidoscopic conditions is truly perilous for employers and insurance carriers alike is illustrated by the 1932 experience of an insurance carrier in Wisconsin, which found that, in one classification, the cost of compensation for silicosis amounted to some nine times the cost of compensation for accidents."

In further emphasis of the danger of not eliminating cases incurred prior to the effective date of a new compensation law, insurance executives have issued the following statement: "Such diseases as silicosis often do not manifest themselves until after many years of exposure. Consequently, during the early years under compensation for such diseases a large proportion of disabilities and deaths resulting therefrom will be due principally to exposures prior to the date when the compensation coverage became effective. In other words, at the start under such a law, industry will have imposed upon it a large volume of 'incurred liabilities' for disabilities and deaths to result in the future from diseases contracted in the past.

"To insure against future contraction of such diseases is one thing. To insure against such future contractions plus assumption of liability for the future results of past contractions is another. Obviously industry has neither accumulated funds nor paid premiums to meet the future losses from the already incurred or potential liabilities mentioned."

Legislation not a cure

From the above discussion it is apparent that definite, adequate and workable legislation for the prevention and compensation of silicosis is needed in many of our states. However, as pointed out in the opening statement, legislation is but one phase of the silicosis question. In no sense can it be regarded as a cure for the hazard. Sound legislation, coordinated with medical and engineering prevention and control, rounds out the three-point solution of the silicosis problem.

Property Taxes in the Election

The property tax, mainstay of local government revenue, continues to meet with popular favor. Voters in five states on Nov. 3 rejected abolition or limitation of property taxes. Only two states approved tax limit proposals.

In Michigan a proposal to abolish the property tax entirely was defeated at the polls. At the same time voters in Minnesota rejected a proposed constitutional amendment which would have abolished the property tax for state purposes, leaving this tax as a source of revenue exclusively for counties, cities and other local governments.

In Colorado, Georgia, and Oregon tax limitation measures were defeated. In Nevada a 50-mill tax limitation was adopted for the first time and in Washington voters decided to continue the present 40-mill tax limit for another two years.

ENGINEERING NEWS-RECORD

Volume 117, No. 24.

Copyright, 1936, by McGraw-Hill Publishing Company, Inc.

EDITOR—F. E. Schmitt. EDITORIAL STAFF—V. T. Boughton, N. A. Bowers, W. G. Bowman, W. W. DeBerard, C. S. Hill, H. W. Richardson, E. J. Cleary

Editorial Offices at 330 West 42d Street, New York

December 10, 1936

Metered Parking

PARKING METERS for regulating curb parking in business areas have become astonishingly popular since their introduction in Oklahoma City a year and a half ago. A study reported in this issue reveals that meters are now operating in fifteen cities, twelve of which adopted them within the year, while four more cities are preparing to use them. The rapid acceptance of the new idea reflects public approval as well as official confidence. No phase of city traffic has proved more perplexing than the control of parking, and while the meter system may not be its ultimate solution it is the nearest approach to effective regulation yet accomplished. There are those who object to the 5-cent meter charge as only another fee to harass the already tax-burdened motorist. But reasonable men will agree that payment for proper facilities is less objectionable than cruising curb space. Merchants are pleased with metered parking; they would not be so if their customers—the public—were displeased.

The Larger Task

IN DECIDING TO MERGE in a new organization the American Society of Municipal Engineers and its rival and associate the International Association of Public Works Officials enter on a new and larger task. The limits of action of the older organizations are reflected in their names. Against this the new American Public Works Association takes as its field the broad range of city public-works administration and engineering. And at no time in the past was this field so replete with problems as today. Disrupted staffs, loss of morale through protracted struggles with PWA and WPA domination, deteriorated facilities and disorganized policies make the undertaking of restoring vigor to the public-works field a task of extreme difficulty. Union of effort is the only hope of success; and for this the new association forms a timely focusing point. But it must be remembered that union is not achieved by merely setting up a society; the opportunity must be recognized by the men who carry on our public-works service. If they join together in the difficult work with a determination to work out their problems and responsibilities, the APWA in providing a gathering-ground for them will perform a valuable service.

An Office Left Vacant

CONGRESS WHEN IT MEETS NEXT MONTH will find itself called on to deal with unusually difficult problems in connection with reclamation. One is the question of raising Grand Coulee Dam to final height, which in effect means deciding on Columbia Basin development as well as on public power for the Northwest. Another is the rumored proposal of western interests to have part of their reclamation debt remitted on the ground that some of the reservoir costs should be charged to flood control, which they claim is a national and not a local responsibility. New projects also are likely to be brought forward. The government needs an effective spokesman to represent the public interest in these large questions. It has had no such spokesman since the lamented death of Elwood Mead last January; the position of commissioner of reclamation still remains unfilled. Now that the election is over there is no reason why appointment should be further deferred. John C. Page, who has carried on as acting commissioner, has won the confidence of all concerned with reclamation; as commissioner he would represent the public interest ably and well. He has earned the promotion to full command. But whether or not the President is willing to promote him, it is time that a commissioner be named forthwith, and that the appointment be given to a man of competence and breadth. Reclamation is no place for a political appointee; the lesson that was learned twelve years ago in the events immediately preceding Dr. Mead's administration is convincing on this score.

Work To Be Done

IF ANY ONE THING emerges more clearly than another from the picture of chaotic attempts to control silicosis by legislation as presented in this issue, it is that engineers have a definite opportunity to assist in working out sound laws and regulations. The basic weakness of the laws that have been passed—laudable attempts to wipe out the disease—is that sufficient knowledge is lacking. The laws and the court decisions based on them seek to make up for this lack of knowledge by unreasonable and burdensome requirements, which after all are ineffective in either checking silicosis or providing for its victims. Most clearly in its relation to rock drilling and other construction operations, the silica-dust hazard depends first of all on engineering development joined to medical research; legislative control can succeed only after the technical and clinical problems are well in hand. This is not to argue that silicosis laws should be repealed. Protective and control legislation is necessary, but only within the scope of present knowledge. As knowledge of causative factors and preventive measures accumulates, the legislation can be progressively strengthened. The work to be done by engineers thus includes study of silicosis conditions and preventive methods, and guidance of legislatures in drafting laws or revising existing laws. Without such work serious injustice may be done to many innocent persons and construction may be severely restricted.

Dam Building Reviewed

AN INTERESTING RECORD OF nearly a century of dam building is set down in this issue, largely in tabular and diagramatic form. It emphasizes the bold advances in height and size of structures built since 1900 and, as the author of article notes, cannot but raise the interesting question of whether dam building has reached a climax in the present decade or whether we will go on to build greater and more notable structures. In the matter of height alone it may well be that few structures will exceed those of the present decade, because of natural limitations, but there are no such limitations on daring or skill in design. Hence there is little reason to believe that more notable structures from an engineering viewpoint will not be built in the future as engineers learn to use reinforced concrete with more assurance or develop means for

protecting steel against corrosive attack. The possibilities of steel in dam design can hardly be said to have been explored. We also have not fully explored the possibilities of buttress dams or multiple domes. Generally speaking, the advantageous sites for dams have been used. The remaining sites, other than those far removed from civilization, can be developed only by the application of unusual skill. This fact stands as a challenge to the dam builders of the future. They may not exceed existing structures in height or bulk but they may be able to surpass them in skillful use of the materials at their command.

Stream-Pollution Control

WHAT FORM of administrative system is best for control and correction of stream pollution is a question that calls for the attention and leadership of the engineering profession. River pollution has increased so greatly that today it is a public evil crying for correction. The prominence given to it by discussion of Ohio River pollution at the recent Pittsburgh meeting of the American Society of Civil Engineers did not do full justice to its wide extent, for the problem is not merely that of finding ways to deal with one river but that of formulating a nationwide program.

Immediate authority over the conditions involved in stream pollution rests with the individual states. Discussions of the subject have repeatedly proposed that full authority over stream pollution be assumed by the federal government, but opposition to federalization is so strong that a system dependent on federal control cannot prove acceptable. The purity or foulness of river waters has no relation to interstate commerce. Yet, since the main difficulties of stream pollution are interstate the federal government is bound to play a part in dealing with them. Some effective plan is essential.

Establishment of a federal authority clothed with power to regulate all matters pertaining to stream quailty and purification would break down the valuable structure of state health and sanitary work that has been built up by a generation of effort. To avoid such injury and obtain the desired end of stream cleanup more effectively it has been proposed that interstate or stream-basin organizations be set up, in which national, state and municipal interests would be integrated. Properly developed, such a plan would preserve the functional authority of the states and would join with it the stimulation and authority of the national interest.

This second plan clearly offers the most promising approach to the problem. It is capable of assuring well-informed and energetic action in evaluating conditions, determining proper requirements, and fixing standards of performance. These preliminary steps would be an immediate preparation for constructive action to improve conditions, and they would also supply a compelling incentive to such action. The whole plan of procedure while utilizing the efficient agencies of the local government would at the same time provide sufficient flexibility in organization to meet local conditions.

Municipal authorities would continue to design, construct and operate local disposal plants for industrial and domestic wastes, under the regular supervision of state boards of health; the latter in turn would be responsible to a central agency charged with formulating and directing the broad policies of interstate pollution control. The federal government would bring to bear on the subject the viewpoint of the national interest. It would contribute a detached technical attitude, the stimulating effect of giving local pollution conditions the publicity due to a problem of broad public concern, and presumably also a sufficient amount of financial aid to assure action.

These are the lines, we strongly believe, along which most effective progress on the control of stream pollution may be expected, in the light of facts that engineering study has revealed. In order to bring a system of the kind into being, however, much further public education would appear to be needed, for the public at large is as yet little conscious of the size and importance of the stream-pollution problem. It is here that leadership by the engineering profession has an opportunity. It would contribute largely to the needed education, and would assist in developing a successful administrative system.

Without Definition

REMARKABLE as it may seem, engineers have never written a definition of the height of a dam. Members of a profession that habitually deals in exact figures are unable to say that such-and-such a dam is so high with any assurance that they will be understood. Often the uncertainty is merely annoying and confusing, but it becomes serious when laws controlling dams use height as the yardstick of regulation. The matter should be settled once and for all.

When it is stated that a dam is 100 ft. high no one knows whether it raises the level of the water 100 ft. or 30 ft. No one knows whether the 100-ft. measure is taken from streambed, from foundation level, or from base of cutoff, or whether its upper limit is spillway lip, deck, or top of parapet.

To be specific let us take Rodriguez dam, pictured on our cover: Excavation and concreting of a narrow fault zone in the canyon floor went to a depth nearly as great as the amount by which the structure rises above ground. Or we may take Grand Coulee, whose foundation rock also is depressed in notches. Shall the height be measured from the local low points?

The profession has discussed and argued these matters until the question "How high is a dam?" has become a standing joke among civil engineers. Yet the situation gives serious cause for concern. Engineers may soon find themselves in the position of having legislators write the definition for them. Precisely this occurred in the case of building height: Legislatures wrote definitions, which proved to restrict building design, materials, and many other factors of cost and feasibility. Legislative definition of dam height might easily have a like restrictive effect on the engineer's work.

Power to put an end to the confusion rests with the directors of the American Society of Civil Engineers. Were that society to set up a competent committee to draft a definition for adoption, the present situation would soon be righted. It is possible that one definition might not meet the needs of dam builders and users, and that two or more terms—for example, design height and hydraulic height—would be preferred. Regardless of personal predilection, however, the definition when once adopted by the society could be used by engineers with confidence that they would be understood by their colleagues. Legal recognition would be certain to follow in due course.

CURRENT NEWS

Ratio of Indirect to Direct Employment On PWA Operations is Determined

Bureau of Labor Statistics finds PWA non-federal projects create 2½ jobs in material production for every job created by actual construction work

The Public Works Administration creates two and one-half times more work in private industries supplying building materials than it does in the building trades constructing its projects, according to a report prepared by the Bureau of Labor Statistics and presented, on Dec. 7, to PWA Administrator Ickes.

The bureau found that during the three years from the inception of the PWA program in June, 1933, up to June, 1936, PWA non-federal projects created 299,000,000 man-hours of employment at the site of the work. Materials ordered during the same period totaled $539,000,000. To produce these materials, 741,000,000 man-hours of labor were required in forests and mines, in mills and factories, and in transportation. These two figures are the basis for the 2½ to 1 ratio.

The report was prepared by a staff of 50 statisticians and clerks of the Department of Labor, who have been working on the subject for the past two years under the direction of Herman B. Byer, head of the bureau's division of construction and public employment. More than a million reports, time sheets, material accounts, contracts, and other records for many hundreds of projects were analyzed in the course of the study.

The figures on direct employment were obtained from the reports regularly sent in by contractors on PWA projects. Reports from more than 40,000 contractors and subcontractors were studied. The figures for indirect employment were obtained through the cooperation of the various industries concerned. Agents of the bureau, utilizing cost accounting methods, made a series of man-hour employment studies covering the major basic materials industries.

Steel, cement, and lumber employment have been completely surveyed. Additional studies in brick and clay products and in plumbing supplies and electrical supplies have advanced to such a stage that it was possible to include them in the calculations with little liklihood of error.

Administrator Ickes points out the studies of the steel industry as being typical of the many studies which were made. Fifteen representative mills operating at a capacity of from 55 to 60 per cent were investigated. All processes required in the production of the finished product were included: the iron and coal mines, transportation, and the steel mills. In this case it was found that about six tons of basic materials are required for each ton of finished steel. The extraction and transportation of these basic commodities require 23 man-hours of employment for each ton of finish product. Employment in the fabrication of finished articles from the raw materials varies from 6 man-hours for fabrication of billots and slabs to 58 hours for structural shapes.

P.W.A. construction accounted for a total of 2,950,000 man-months of employment in the steel industry, according to the survey. In cement production, where 126.3 man-hours of labor are required for every hundred barrels, total employment was 484,000 man-months. In the lumber industry, P.W.A. orders accounted for 565,000 man-months of employment.

Delaware Aqueduct Shaft Bids To be Asked Soon

Bids for constructing shafts for part of the Delaware River Aqueduct pressure tunnels will soon be asked, according to a statement by the Board of Water Supply, New York City. The contemplated work, covering contracts 332 and 336, will probably be advertised Dec. 16.

The power contract will be for sinking and lining three shafts (2, 2A and 3) of the Rondout-West Branch tunnel, in the towns of Wawarsing and Gardiner, Ulster County, N. Y. These shafts range from 825 to 1,550 ft. deep and will connect with 13½-ft. tunnel. Contract 336 covers shaft 17 of the West Branch-Kensico tunnel and shafts 18 to 23 inclusive of the Kensico-Hill View tunnel, in the towns of North Castle, Mt. Pleasant and Greenburgh and the city of Yonkers, Westchester County. These shafts will have depths of 320 to 920 ft. and will give access to tunnels 15 to 19½ ft. in diameter.

Preliminary information may be obtained from the chief engineer of the Board of Water Supply, 11th floor, 346 Broadway, New York City.

Western State Engineers Ask Water Resource Studies

The Association of Western State Engineers, meeting in Santa Fe, N.M., Dec. 3-5, gave its support to plans for an increase in water resource study. This action was contained in two resolutions, one supporting the program of water studies recommended in a recent report of the National Resources Committee on deficiencies in hydrologic data, (*ENR*, Nov. 5, 1936, p. 641), and the other stressing the need for groundwater investigation.

The technical sessions emphasized the problems arising from water use and control. Edward Hyatt, state engineer of California, spoke on the coordination of irrigation, power, and flood control development, and G. D. Macy, formerly state engineer of New Mexico, spoke on the regulation of dam construction. J. C. Stevens, water consultant for the National Resources Committee, discussed the necessity of state and federal cooperation in securing hydrologic data. The second day's session included a discussion by Sidney T. Harding of the University of California, of the probability of the drought cycle, and a paper on uniform groundwater laws by George S. Knapp, chief engineer of the Kansas division of water resources. M. C. Hinderlinder, state engineer of Colorado, discussed the development of small waters in storage reservoirs for supplemental supply for lands already under irrigation.

These technical sessions were featured by an unusually large time allowance for a general discussion, which was well sustained.

The newly elected officers are: president, J. S. James, state engineer of Montana; vice-president, John G. Quinn, state engineer of Wyoming; member of executive committee, Edwin Stuart, state water commissioner of Arizona.

Washington Contractor Killed By Falling Beam

A 2-ton floor beam, falling 50 ft. from the Benning viaduct now under construction in Washington, D. C., struck and killed John L. McDonald, president of the Federal Steel Erecting Co., which was erecting the steelwork on the viaduct. Two other men, employees of the erecting company, were struck and critically injured. McDonald standing by the crane erecting the steel, saw the beam fall and attempted to escape but tripped and, falling in the path of the beam, was struck on the head.

The cause of the accident has not been determined. It appears that the floor beam and three joists which fell at the same time were being fastened in place when they dropped.

Public Works Associations' Merger Completed

The joint administrative board of the American Society of Municipal Engineers and the International Association of Public Works officials announced on November 24 that a vote of the membership of these societies on the proposed constitution of the American Public Works Association, to be formed by their merger, had resulted favorably.

The members of the American Society of Municipal Engineers voted in favor of the merger 278 to 11, and the members of the International Association of Public Works officials voted in its favor 203 to 4. The proposal, therefore, stands approved, and the new constitution will become effective on January 1, 1937.

Elections are now under way for officers of the new society.

Marshal Ford Dam Put Under Contract

Reclamation Bureau lets contract for dam on Colorado River of Texas on a six-million-dollar bid

The Bureau of Reclamation has awarded a contract for construction of Marshal Ford Dam on the Colorado River of Texas to Brown & Root, Inc., of Austin, and the McKenzie Construction Co., of San Antonio, on their joint bid of $5,781,000, the lowest bid of three received.

Marshal Ford Dam is to be constructed in two stages; ultimately the dam will be 265 ft. high, but the present contract calls for construction of the first stage, a dam 190 ft. high.

The dam is intended to provide control of the floodwaters of the Colorado River of Texas. It is one of a series of power and flood control dams on that river above Austin. Although Marshal Ford Dam is being built by the Bureau of Reclamation, the other dams in the series will be built by the Lower Colorado River Authority, an agency created by the state of Texas. The low dam now to be constructed at Marshal Ford, about 18 miles above Austin, will be a concrete gravity dam with a crest length of about 2,325 ft. A 30-ft. embankment 1,100 ft. long will be built, as a part of this same contract, at the left abutment.

The low dam will create a reservoir with a capacity of about 600,000 acre-ft., while the high dam ultimately to be built will increase the capacity of this reservoir to about 3,000,000 acre-ft. and will permit generation of about 60,000 kw. Although no power plant will be constructed at this time, penstocks will be built in the low dam for use when the high dam is constructed; these will be capped for the present.

The outlet works in the low dam will consist of 24 8½-ft. tunnels controlled by 102-in. paradox gates. The spillway, 730 ft. long, will be in the central section of the dam.

Ruling Made on Liability From Crossing Signals

An opinion given by Attorney General Bailey of Arkansas as to the liability for accidents arising from the proper functioning of railroad crossing signals of the barrier type holds that no liability rests on either the highway commission or the railroad. The opinion relates to a device of the type in which on the approach of a train a barrier automatically rises from the road to a height of 10 in. Several of these devices are now being installed at various locations in Arkansas. They are being purchased and installed by the state highway commission and maintained by the railroad company, and it was desired to determine what liability would rest on the parties to the arrangement should accidents result from autos striking the barrier.

The attorney general stated that neither the state nor the highway commission could be sued because of such accident, because the state constitution provides that the state cannot be sued, and the supreme court has held that the highway commission is an agency of the state. Railway companies whose duty it was to maintain and operate the devices would not be liable for such accidents, but would be liable for injuries to persons or property resulting from the failure of the device to function due to negligence on the part of the railroad.

Iowa Has Eliminated 92 Grade Crossings

During the last two years, work has been started or has been completed on the elimination or improvement of 92 railroad grade crossings on Iowa highways, under the direction of the Iowa State Highway Commission. The work has been done with grants from the Federal Bureau of Roads amounting to $5,600,000; no contributions from the railroads were involved.

Sixteen old overpasses have been improved. At six points traffic signals have been installed at an average cost of $3,000 to $4,000. Underpasses were built, at costs varying from $37,000 to $108,000, at 14 crossings. Relocations were made at six places at costs ranging from $5,000 to $102,000. Elimination of 56 crossings has been made possible by overhead passes. The cost of this type of structure varied from $7,000 to $342,000.

Contracts were let on November 24 for three other grade crossing elimination projects.

Three Housing Contracts Let

The PWA has let contracts for three housing projects and has ordered another project redesigned to lower its cost.

Contract for the superstructure of Laurel Homes, the $6,500,000 slum clearance project in Cincinnati, was awarded to the David Gordon Construction Co. on its low bid of $3,690,000. Work will start at once. The foundation work will be completed this month. Laurel Homes will provide accommodations for 925 families, in three- and four-story apartments.

The Ring Construction Co. of Minneapolis, Minn., has been awarded the contract for superstructures for Brand Whitlock Homes, the $2,000,000 project in Toledo, Ohio. The Ring company's bid was $1,284,000. Foundations on this project are nearly completed, and work on the superstructure will start at once. The project includes three-story apartment houses, two-story flats and two-story group houses, and will house 264 families.

Superstructures for Logan Fontenelle Homes, the $2,000,000 project in Omaha will be constructed by Peter Kiewit Sons Co., of Omaha. The amount of the accepted bid was $1,283,000. Logan Fontenelle Homes includes 284 attractive apartments.

Public Works Administrator Ickes has ordered that Parkside, the housing project in Detroit, be redesigned to make possible lower prices for its construction. Bids for erection of the building were opened Oct. 20 on the basis of present plans and were found to be too high to permit low rents to be achieved. Re-study of the development has been put under way by the Housing Division. The new plans will be put out for bids immediately upon the completion of this new study.

Pressure Increases for Reclamation

Washington Correspondence

With great numbers of farmers from the drought region moving into the northwest, an increasingly insistent demand for irrigation in the Columbia Basin is developing. Senator Borah of Idaho and Senator Schwellenbach of Washington have joined forces to push for an appropriation for the high dam at Grand Coulee. A delegation of citizens in the northwest will visit Washington in the near future to ask that $20,000,000 be appropriated to cover work that could be done on the dam during the next fiscal year. Congress already has authorized $184,000,000 for the project.

At the same time the National Reclamation Association is working for a bill to relieve water users on western irrigation projects of such portions of the carrying charges as can be charged to flood control on such dams as the Pathfinder and Seminoe on the North Platte River or the Elephant Butte on the Rio Grande.

The association also favors legislation that will allow power revenues from irrigation projects to accrue for the benefit of the project or for the tributary territory. A strong precedent for such procedure exists in the use of Boulder Dam money for development in the upper basin of the Colorado River.

London Subway to be Extended

The London passenger transport board will apply to Parliament early in 1937 for permission to extend the 23-mi. Morden-Edgware line of the underground railway from its Edgware terminus to Bushey, a distance of about three miles. The proposed new line would serve an area in which large housing developments and moving picture studios are growing rapidly.

The cost of subway construction in London runs about $3,750,000 per mile, but a considerable part of the extension from Edgware would be on the surface, substantially reducing the mileage cost.

First Water Admitted To Loup River Canal

Water flowed in the canal system of the Loup River power project for the first time on Dec. 1. Only a small volume of water, averaging about 50 sec.-ft., was admitted in order to season and render watertight the walls of the canal.

It is planned to release enough water to fill the canal to a level near the crest of the Lake Babcock reservoir weir and to continue to release it in volume sufficient to maintain that level without going over the weir. The canal system downstream from the weir to the Columbus Power House will be seasoned next spring.

Meanwhile machinery is being installed in the two power houses of the project, and the connecting transmission line is being built.

Outlet Gate Contract Let for Coulee Dam

Gates for first tier of outlets through Grand Coulee dam awarded on a bid of $1,454,000

Award was announced on Dec. 3 of a contract for manufacture and delivery of twenty sets of gates for the first tier of outlet works in Grand Coulee Dam at the Hardie-Tynes Manufacturing Co., of Birmingham, Ala., on its bid of $1,454,000. This bid was the lowest of five.

Each set of gates consists of one ring-follower gate, 102 in. in diameter, with hoist and appurtenances; one paradox gate, 102 in. in diameter, with hoist, motor, hoisting switch and other appurtenances, and sections of steel lining for the outlet conduit. The gates are to be delivered four sets at a time in 210 days, 232 days, 255 days, 277 days and 300 days.

There will be three tiers of outlet work in the central section of the dam. Each tier will have twenty conduits controlled by separate gates similar to those now awarded. The gates involved in the present contract will go into the lowest tier of outlets, about 80 ft. above the foundation of the dam. The middle tier will be 100 ft. higher, and the upper tier another 100 ft. above that.

The sixty outlets in the completed high dam will have a combined capacity of 273,000 sec.-ft. This is in addition to the 81,000-sec. ft. capacity of the 18 penstocks serving the power house. Each of the sixty outlet conduits will be 8½ ft. in diameter. The control gates will be installed in tandem, with the ring-follower gate above the paradox gate. The ring-follower gate will be used in emergencies and when it is necessary to inspect and repair the paradox gate.

The spillway, with a capacity of 1,000,000 sec.-ft., will be in the central section of the dam, above the three tiers of outlets.

Diversion of the Columbia River was begun a few weeks ago and the present river channel is expected to be completely dried by next March. More than 1,500,000 cu.yd. of concrete have been placed in the west abutment to date, and pouring in the east abutment is getting under way.

Aerial Explorations Photo

DEPRESSED HIGHWAY SERVES THE TRIBOROUGH BRIDGE

WHEN New York's Triborough Bridge was opened last July, the Queens approach was not completed, and traffic has had temporarily to use existing Astoria streets. This inconvenience is now ended, and a depressed roadway serves the motorist through twenty blocks of built-up property. Descending the ramp from the bridge (left corner of the view), he first passes beneath the rapid transit elevated structure and then under a half dozen cross street bridges and then beneath the elevated line of the New York Connecting Railroad.

The depressed highway provides two 42-ft. roadways, separated by a safety strip. Marginal streets on either side at the surface level serve local traffic. Beyond the point where the depressed highway comes to grade, the approach divides into two parts, one for automobile traffic only, curving left to join Grand Central Parkway, the other continuing straight ahead along Astoria Avenue and available to trucks and commercial traffic.

Hines Held Originator Of Center Traffic Line

Edward N. Hines was hailed as the originator of the center traffic line for marking highways and honored for this achievement at the annual banquet of the American Automobile Association in Detroit on Nov. 20, by the award of a plaque given by the B. F. Goodrich Co.

The Goodrich Company some time ago began a search throughout the country for the originator of the center traffic line idea. The decision as between the many claims received was reached by a committee of which Thomas P. Henry, president of the American Automobile Association, was chairman. The other members were Austin F. Bement, formerly executive secretary of the Lincoln Highway Association, and Chris Sinsabaugh, editor, Automotive Daily News.

Mr. Hines has been a road commissioner of Wayne County, Mich., since the inception of the board of Wayne County commissioners over thirty years ago.

New Haven Will Build Two Sewage Plants

The city of New Haven is preparing plans for the construction of two sewage treatment plants which, it is believed, will alleviate the pollution now existing in the waters of New Haven harbor. This action is taken on the recommendation of the Connecticut state water commission.

The present work follows the recommendations resulting from a survey conducted more than ten years ago. The recommendations made at that time called for the construction of four plants, the East St. plant to serve the center of the city, another plant to serve the same section, a $500,000 plant on the Boulevard, and a $350,000 plant on Meadow St. It is planned at present to construct the boulevard and Meadow St. plants. Three city wards must be provided with a sewer system before the second plant in the center of the city can be built, and this work is therefore being postponed.

The present schedule calls for completion of plans for the Boulevard plant by Feb. 1, 1937, and completion of construction by June 1, 1938. The plans for the Meadow St. plant are to be ready by Jan. 1, 1938, and work finished by Dec. 31, 1939.

Wider North Approach Planned For Chicago River Bridge

Divided and widened roadways are being planned for the boulevard serving as the north approach to the new Outer Drive bridge over the Chicago River in Chicago. From the present terminus of the north viaduct approach at Ohio St., Lake Shore Drive, which is now a single roadway in the half-mile section to Oak St., will be doubled in width and will be formed in two separated roadways. At Oak St., which is a main east and west thoroughfare, Lake Shore Drive and Michigan Ave. converge, becoming a single boulevard consisting of two drives separated by a parkway strip. Under the present plans, this roadway will be increased in width by the addition of another drive and separating parkway strip, so that a triple drive will be available.

This widening plan is part of a proposed program announced several weeks ago by Robert J. Dunham, president, Chicago Park Board, for widening all of the lake front boulevards from Evanston to South Chicago, a distance of 15 miles. Preliminary plans for this major improvement have been prepared by the engineers of the park board.

Funds for WPA Near Exhaustion

Washington Correspondence

Due to the approaching exhaustion of current funds the Works Progress Administration is now busy cutting its rolls. It is expected that Congress will be asked to supply an additional $500,000,000, which will be needed to carry the agency on to the end of this fiscal year.

The WPA plans to cut relief rolls by about 175,000 men. This is in addition to the 250,000 men to be dropped from drought relief programs, of whom 60,000 will be taken over by the Resettlement Administration. These cuts would bring the total relief figure down to about 2,300,000, as compared with a peak of 3,000,000 last January.

WPA has also been cutting down its administrative staff in order to meet possible changes that may be suggested by the President's committee now studying all relief agencies with a view to reorganizing them on a more economical basis. More than 5,000 administrative workers have been dropped since Sept. 1, when the total of such workers was 35,000.

These reductions in personnel have aroused a protest by the mayors of a number of cities who called upon WPA executives last week and insisted that relief must continue. According to the mayors, headed by Mayor LaGuardia of New York, the $1,450,000,000 appropriated by the last Congress was hardly half enough to meet the requirements. The mayors presented a program calling for continued expenditures of at least $5,500,000 daily by WPA.

Re-employment itself is causing trouble for WPA. The re-employment process has tended to draw away the skilled workers leaving still on the rolls the unskilled and the white collar workers and creating serious difficulties in the staffing of WPA projects.

Despite the unsettled conditions confronting them, WPA administrators are confident that relief work will be continued. New projects are being approved provided they can be finished by Jan. 20, and supplemental allotments are being made where the funds are completely exhausted.

Treasury figures show that there is now on hand and available out of the current WPA appropriation $87,000,000, which will, however, be exhausted by Jan. 20.

New York State Protects Engineering Practice

In the year ending June 30, 1936, a total of 141 cases of reported illegal and unprofessional practice were handled by the New York State Education Department under the engineers' registration law. Out of 125 cases involving unlicensed practice or unlawful use of the designation engineer by individuals or corporations, 66 were corrected without resort to court action, 58 were still pending correction or adjustment, and one case was referred to the attorney-general. The remaining sixteen complaints related to improper practices of registered professional engineers or land surveyors; of these, fourteen were disposed of without requiring disciplinary procedure, and two cases are still awaiting further investigation or hearings.

Typical of many of the cases handled is that of a well advertised commercial school giving a short course in the operation of diesel engines and styling itself a "Diesel Engineering School." After complaints had been received, the public authorities ruled, under Article 66 of the state education law, that it was unlawful for an unauthorized institution to call itself an engineering school. To satisfy the requirement of the state education department, the name of the institution has now been changed from Diesel Engineering School to Diesel Engine Institution.

SOCIETY CALENDAR

AMERICAN SHORE AND BEACH PRESERVATION ASSOCIATION, annual meeting, Washington, D. C., Dec. 14.

ASSOCIATED EQUIPMENT DISTRIBUTORS, annual meeting, New Orleans, La., Jan. 10-12.

CANADIAN CONSTRUCTION ASSOCIATION, annual convention, Ottawa, Canada, Jan. 11-13.

AMERICAN ROAD BUILDERS ASSOCIATION, convention and highway exhibit, New Orleans, La., Jan. 11-15.

UNIVERSITY OF COLORADO, highway engineering conference, Boulder, Colo., Jan. 14-15.

AMERICAN ENGINEERING COUNCIL, annual assembly, Washington, D. C., Jan. 14-16.

AMERICAN INSTITUTE OF CONSULTING ENGINEERS, annual dinner meeting, New York, N. Y., Jan. 18.

AMERICAN SOCIETY OF CIVIL ENGINEERS, annual meeting, New York City, Jan. 20-23.

ENGINEERING INSTITUTE OF CANADA, annual meeting, Montreal, Canada, Jan. 29-30.

AMERICAN CONCRETE INSTITUTE, annual meeting, New York, N. Y., Feb. 25-27.

NEW YORK STATE SEWAGE WORKS ASSOCIATION, annual meeting, New York City, Jan. 21-23.

AMERICAN WOOD PRESERVERS ASSOCIATION, annual meeting, New Orleans, La., Jan. 26-28.

NATIONAL PAVING BRICK ASSOCIATION, annual meeting, Detroit, Mich., Jan. 1-29.

CONNECTICUT SOCIETY OF CIVIL ENGINEERS, annual meeting, New Haven, Conn., Feb. 16-17.

SOUTHWEST ROAD SHOW AND SCHOOL, Wichita, Kansas, Feb. 23-26.

ASSOCIATION OF HIGHWAY OFFICIALS OF NORTH ATLANTIC STATES, annual convention, New York, N. Y., Feb. 24-26.

MINNESOTA FEDERATION OF ARCHITECTURAL AND ENGINEERING SOCIETIES, annual convention, St. Paul, Minn., Feb. 26-27.

LICENSE EXAMINATIONS

MICHIGAN, examination for architects will be held at the University of Michigan and for engineers and surveyors at the University of Michigan at Michigan State College, at Michigan College of Mines, and at Ironwood, on Dec. 28-30.

Officers elected by the IOWA WASTE DISPOSAL ASSOCIATION include: president, W. E. Galligan, assistant professor of civil engineering at Iowa State College; vice president, E. E. Truckenmiller, Sibley, Iowa; secretary-treasurer, L. J. Murphy, Ames, Iowa; directors, A. J. Sedlacek, Pocahontas, Iowa; E. E. Dye, Mason City, Iowa; representatives to the Iowa board of control, E. L. Waterman, Iowa City, Iowa, and A. H. Wieters, Des Moines, Iowa.

Walsh-Healey Act Restricts Dealers

Washington Correspondence

Secretary of Labor Perkins has issued a new regulation governing the administration of the Walsh-Healey Act which provides that when dealers fulfill contracts for government purchases subject to the act by direct shipment from the manufacturer rather than from their own stocks, they are acting as the manufacturers' agents, and that the regulations will apply to the dealer and also to the manufacturer.

The text of the order is: "Whenever a dealer, to whom a contract within the act and regulations has been awarded, causes a manufacturer to deliver directly to the government the material, supplies, articles or equipment required under the contract, such dealer will be deemed the agent of the manufacturer in executing the contract. As the principal of such agent, the manufacturer will be deemed to have agreed to the stipulations contained in the contract."

Industry appears, in general, to be willing to conform to the requirements of the act. As of November 28, 234 separate contracts falling within the Walsh-Healey limitations had been awarded for a great variety of products.

Included in the list of successful bidders and, therefore, of conformers with the act are many large concerns: General Electric, Westinghouse, Endicott Johnson, Standard Oil of Indiana, Sinclair Refining, Colgate-Palmolive-Peet, duPont, Atlas Powder, Allis-Chalmers, American Bridge, and the Aluminum Company of America, were among them.

At present, two industries, the auto builders and the machine tool builders, appear to be unwilling to come under the restrictions of the act.

When recently the Resettlement Administration tried to buy 28 trucks, the truck builders split their bids so as to bring the offers below the $10,000 deadline; on readvertisment they declined to bid except on one item, also under $10,000. The contract was finally divided among the various bidders so that no one became subject to the restriction. Subsequent truck purchases have been made through local dealers. Secretary Perkins' new ruling will doubtless affect this practice.

The Navy is reported to be worried about the refusal of machine tool builders to bid. With private orders already booked up well into the future, this industry feels little need of government contracts.

Cable Wrapping Begins On Golden Gate Bridge

Six cable wrapping machines began work last week, wrapping the main suspension cables of the Golden Gate Bridge, a job which will last until February.

Riveting of the top cord splices has been completed, and the travelers are being brought back from the center of the span to the towers for dismantling. On the way they are setting the rest of the roadway and sidewalk stringers, the curbs, and the handrailing.

Paving of the Marin approach span was completed on November 30.

Personals

GEORGE H. SCHNITZER, A. A. STEPHENS and JOHN A. OLSON have formed the Olson Engineering Co. at Cleveland, Ohio.

G. P. WILLOUGHBY, assistant bridge engineer for the Alabama highway department, has resigned to join the engineering staff of the Virginia Bridge & Iron Co.

JOHN J. CROAK has been appointed chief engineer of the Pittsburgh department of public works, succeeding HENRY D. JOHNSON, JR., who has retired. Mr. Croak has been connected with the department for the past 30 years and for the past several years has been division engineer of the bureau of design.

WILLARD T. CHEVALIER, vice president of the McGraw-Hill Publishing Co., has been appointed by the Secretary of State as a representative of the United States on the Permanent International Commission of the Permanent International Association of Road Congresses. Mr. Chevalier is president of the American Road Builders' Association.

T. R. AGG, dean of the engineering department of Iowa State College, was given the George H. Bartlett award for achievement in highway work at the recent meeting of the Highway Research Board. The basis for the award was Dean Agg's research work in highway engineering and economics for the Iowa Engineering Experiment Station. The Bartlett award is given by the American Association of State Highway Officials, the American Road Builders Association, and the Highway Research Board.

Brief News

WAGE LEVELS ON THE PWA reached in September the highest point since the beginning of the program in July, 1933. The average pay of PWA workers on federal and non-federal programs during September was $.776 per hour as compared with a three year average of $.652. The lowest average wage during the course of the program was that of $.528 in October 1933.

CONSTRUCTION has started on the last section of the main canal of the Maverick County irrigation district. This 57-mile section is a PWA project, for which an allotment of $2,422,000 has been made. The first 23-mile section of the canal was completed some time ago, reclaiming and placing under irrigation a large body of ranch land. The 90-mile canal has its intake on the Rio Grande, and irrigation is by gravity flow. When in full operation, the project will provide water for 67,000 acres of land. The second section is being constructed by Hardwicke & Company.

SHEEPSHEAD BRIDGE, the proposed span across Sheepshead Bay at Ocean Ave., Brooklyn, N. Y., need not be put under construction before November, 1937, according to a decision of the War Department. The War Department permit originally required that construction be started before November 2, 1936 and completed by November 2, 1938, but the present extension moves these dates ahead one year. Although the $350,000 Sheepshead Bay Bridge is on the preferred list of the New York City Department of Plant and Structures, federal funds have not been alloted for it.

THE RAILWAY LINE from Senneterre to Rouyn, in northern Quebec, will be built for the Canadian National Railway by the Fred Mannix Construction Co. of Calgary, Alberta. The grading will cost $1,250,000. The railway company will supply steel rails and ties along the 100.5-mi. route, erect the telegraph line along the right-of-way, and build ten or 12 stations. The work of clearing the right-of-way is beginning at once. This line has been the subject of contention between the Canadian National Railway and the Canadian Pacific Railway, both of which attempted to obtain permission to build it. However, while the Canadian Pacific Railway's application to the Quebec legislature was held up by the fall of the Taschereau government, the Canadian National Railway obtained permission for construction from the federal parliament. (*ENR*, July 16, 1936, p. 100).

THE WAR DEPARTMENT has approved plans submitted by the board of supervisors of Suffolk County, New York, for a fixed bridge to be constructed under the authority of state law across Shelter Island Sound from South Ferry, Shelter Island, N. Y. to North Haven, near Sag Harbor, L. I., in New York. The proposed bridge will provide a principle navigation opening having a horizontal clearance of 565 feet and a vertical clearance of 75 feet above mean high water throughout the central 400 feet of this span. The total length of the bridge between abutments will be 2,520 feet with eight piers between shore lines. Approval has also been granted for a fixed bridge to be constructed across Shelter Island Sound from Cleaves Point near Greenport, L. I., to Shelter Island, N. Y.

APPROVAL OF THE TRUCKEE RIVER AGREEMENT by the directors of the Truckee-Carson irrigation project permits formal award of the contract for construction of Boca Dam in California to the George W. Condon Co. of Omaha (*ENR*, Nov. 5, 1936, p. 661). The agreement provides for the distribution of the waters of the Little Truckee and Truckee Rivers.

IMMEDIATE PASSAGE of the proposed new building code for New York City was requested in a letter sent to the president of the Board of Aldermen and to Mayor LaGuardia by the New York Building Congress, an organization made up of engineers, architects, contractors, material suppliers, and labor and real estate interests in New York City. The letter stated that all the technical questions but one, concerning the code had been satisfactorily settled and all the necessary hearings had been held. The letter urged that, especially in view of the large amount of public criticism of building standards in New York City recently current, immediate adoption of the code should be rushed. It was the opinion of the Congress that the single question remaining to be settled, the respective jurisdictions of the Board of Standards and Appeals and the Board of Buildings, need not hold up the passage of the code as a whole.

U. S. Bureau of Reclamation Photo

GRAND COULEE DAM READY FOR RIVER DIVERSION

Preparations are under way to divert the Columbia River at Grand Coulee Dam from its original channel to sluiceways and openings through the west end of the dam. This view, looking eastward from the downstream side of the west spillway section, shows the timber wall that will seal off the connecting end of the crib cofferdam now being built in mid-river. Full diversion of the river will not take place until some time next spring, when the mid-river cofferdam has been completed.

Obituary

CHARLES P. WRIGHT, a railroad contractor, died on Nov. 30 in Portage La Prairie, Manitoba, at the age of 88. Mr. Wright built much of the old Grand Trunk Ry. in the West.

JOHN J. VAIL, construction engineer for the Pennsylvania Railroad, died on Dec. 2 in Rahway, N. J., at the age of 59. Mr. Vail had been connected with the Pennsylvania since his graduation in 1898 from Rutgers University.

PHILIP CENEDELLA, president of Cenedella & Co., general contractors, died on Dec. 2 in Milford, Mass., at the age of 64. Mr. Cenedella did much highway construction in Massachusetts, held a contract for a 2-mi. section of New York City's Catskill aqueduct, and had recently held contracts for the widening work on the Cape Cod Canal.

AURELIEN BOYER, for some years principal of l'Ecole Polytechnique in Montreal, died in that city on Nov. 25 at the age of 63. Mr. Boyer was a graduate of l'Ecole Polytechnique and served with several government engineering departments, including the Dominion department of public works, before entering business, which he left when taking his academic position.

CHARLES M. BABCOCK, for 15 years highway commissioner of Minnesota, be-

fore his resignation in 1932, died Nov. 21 at Elk River, Minn., aged 65. Mr. Babcock, formerly in business in Elk River, was appointed in 1910 a member of a three-man highway commission. In 1917, when the state voted to replace that commission by a single commissioner, Mr. Babcock was appointed to the position. Mr. Babcock was a past president of the American Association of State Highway Officials and of the American Road Builders Association. Since his resignation in 1932 from the Minnesota highway commission, Mr. Babcock has been active in the affairs of the associations. He has twice been a delegate to the International Highway Congress.

THERON M. RIPLEY, 58, consulting engineer of Buffalo, N. Y., died in that city on Nov. 30. Mr. Ripley graduated from Marietta College, and from 1890 to 1898 was engaged in railroad and hydro-electric work, principally in Montana. In the latter year he went to Manila and for three years had charge of park and street work. After four years of bridge and canal work, he entered the barge canal office of the New York State engineering department, serving with that department until 1913, when he was transferred to the state highway department. During the war he held the rank of major in the Engineer Corps. After the war he returned for a time to his work on the barge canal but later went into consulting work.

CONSTRUCTION STATISTICS FOR THE WEEK

ENGINEERING construction awards for the week total $59,244,000, compared with the average week to date for the year of $45,082,000. This total is made up of private, $28,863,000; public $30,000,381; federal, $12,567,000 and state and municipal, $17,814,000. Corresponding values a week ago are; total, $74,328,000; private, $38,517,000; public, $35,811,000; federal, $6,325,000; state and municipal, $29,486,000. A year ago the volume corresponding to this week's values was: total, $35,037,000; private, $4,077,000; public, $30,960,000; federal, $2,388,000 state and municipal, $28,572,000.

Increases for the week are registered in sewerage, commercial buildings, earthwork, drainage and waterways and unclassified. Private unclassified is high in reflection of heavy rail buying by the railroads. The classified subtotals are: waterworks, $1,160,000; sewerage, $2,100,000; bridges, $1,815,000; industrial buildings, $5,030,000; commercial buildings, $7,282,000; public buildings, $2,427,000. earthwork, irrigation, waterways, $11,450,000 and unclassified, $20,679,000.

The larger awards for the week include: cement plant, Universal Atlas Cement Co., Hudson, N. Y., $1,000,000; pulp mill, first unit at Plymouth, N. C., Kieckhefer Container Co., Delair, N. J., $1,000,000; group of dwellings, Economy Housing & Development Corp., Springfield, N. Y., $500,000; superstructure, 11 story building, Dartmouth Building Trust, Boston, Mass., $1,500,000; apartment for M. Goetz Jackson Heights, N. Y., $600,000; highway awards by Iowa, $1,254,000 and by North Carolina, $657,000; conduit No. 17, Moffat Tunnel Extension Project, Denver, Colo., $605,000; sanitary sewer system and outfall line, WPA forces, San Jose, Calif., $645,000; service gates and emergency gates, Grand Coulee Dam, Wash., Bureau of Reclamation, Denver, Colo., $1,341,000; lock and dam on Warrior River to replace locks 10, 11, 12, U. S. Corps of Engineers, Tuscaloosa, Ala., $3,331,000; Marshall Ford Dam, Bureau of Reclamation Austin, Tex., $5,781,000; airport improvements. East Boston, Mass., $2,500,000; and rails Chesapeake & Ohio R.R., $1,330,000; Atcheson Topeka & Santa Fe Ry. $6,000,000; Chicago, Milwaukee & St. Paul R.R., $2,849,000; Missouri Pacific Lines, $1,352,000; Delaware, Lackawanna & Western R.R., $735,000; Erie R.R., $749,000; and the Baltimore & Ohio R.R., $1,800,000.

New capital is very low for the week, $2,828,000 in new state and municipal financing through bond issues and a transfer from federal to private investment financing through sale by RFC of PWA bonds, $3,972,000.

CONTRACTS
(Thousands of Dollars)

	Weekly Average Dec. 1935	Prev. 4 Weeks	Week Dec. 10 1936
Federal Government	$14,735	$5,804	$12,567
State and Municipal	37,038	23,259	17,814
Total public.....	$51,773	$29,063	$30,381
Total private....	7,103	22,687	28,863
Week's total....	$58,876	$51,750	$59,244
Cumulative to date:			
1935..$1,439,027,000	1936..$2,254,116,000		

NEW PRODUCTIVE CAPITAL
(Thousands of Dollars)

1936	Week Dec. 10	Cumulative
State and municipal	$6,800†	$490,910†
PWA non-federal...	—3,972†	164,727†
RFC loans.....	.....	26,663
Corporate issues...	.....	243,502
PWA loans, Private	.....	—1,665*
Total Non-Federal	$2,828	$924,137
Federal	.....	691,237
Federal	.....	.....
Total new capital	$2,828	$1,615,374
Cumulative to date:		
1935..$2,659,661,000	1936..$1,615,374,000	

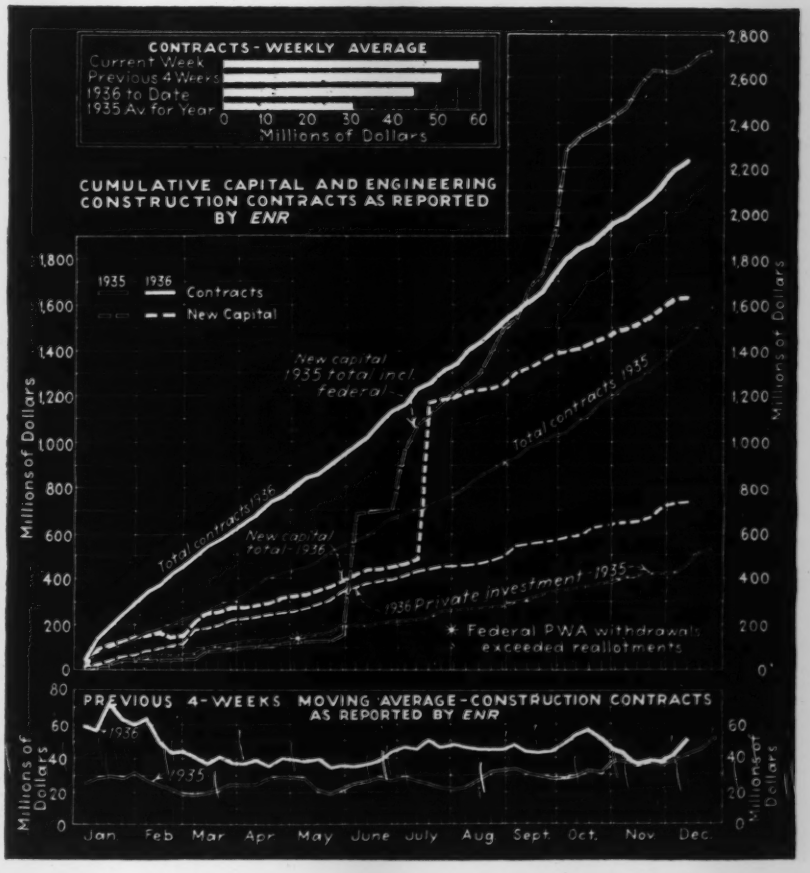
*** Bond sales in this classification exceed reallotments during current year.**

† Includes transfer from federal to private financing through sale by RFC of PWA Bonds.

Note: These figures include private bonds, and stocks sold for productive purposes; state and municipal bonds for construction; PWA loans and grants to states and municipalities. RFC direct purchase of bonds for "self liquidating" projects, and 25 per cent of WPA construction appropriations.

INDEX NUMBER

ENR Cost	1913 = 100	1926 = 100	ENR Volume	1913 = 100	1926 = 100
Dec., 1936	220.67	106.07	Nov., 1936	159	70
Nov., 1936	212.70	101.67	Oct., 1936	178	78
Dec., 1935	194.90	93.69	Nov., 1935	171	75
1935 (Av.)	195.22	93.84	1935 (Av.)	135	58
1934 (Av.)	198.10	95.23	1934 (Av.)	114	50
1933 (Av.)	170.18	81.80	1933 (Av.)	102	47



Current Construction Unit Prices

Marshall Ford Dam, Texas

BIDS for the construction of the Marshall Ford dam on the Colorado River in Texas, 15 mi. northwest of Austin, were opened Oct. 20, 1936, by the U. S. Bureau of Reclamation. Ultimately the project provides for a concrete straight gravity dam 265 ft. high; the present work contemplates a concrete dam 190 ft. high and 2,325 ft. long at the crest, with a left abutment embankment 30 ft. high and 1,100 ft. in length. The dam will be built in sections with grouting pipes installed for the vertical contraction joints between the sections, and is scheduled for 900 days completion with PWA minimum hourly wage rates stipulated of $1.00 for skilled and 40c. for common labor. The government furnishes f.o.b. Rutledge, 15 mi. distant on the A.T.&S.F.R.R., cement, admixtures, reinforcing steel, sewer and drain pipe, all miscellaneous metal work and machinery and other materials forming the completed dam except aggregates, and materials required in construction procedure. H. P. Bunger, Austin, is construction engineer for the Bureau.

The following tabulations list the unit prices and totals of the three low bidders: (A) Brown & Root Inc. and McKenzie Const. Co., Austin, (contract), $5,781,235; (B) Utah Const. Co., Ogden, Utah, $5,909,049; (C) W. E. Callahan Const. Co., Dallas, Tex., $7,322,496.

MARSHALL FORD DAM, COLORADO RIVER, TEXAS

Item	A	B	C
1. Diversion, care of river—total	$25,000	$88,000	$80,000
2. Excav., strip borrow pits—10,000 cu.yd.	.25	.26	.27
3. Excav., strip embank.—7,500 cu.yd.	.32	.51	.27
4. Excav., common, foundation—450,000 cu.yd.	2.00	.90	.40
5. Excav., rock foundation—310,000 cu.yd.	2.50	1.70	2.50
6. Excav., earth, toe drain, cutoffs—5,000 cu.yd.	.96	.57	1.00
7. Excav., rock, toe drain, cutoffs—130 cu.yd.	12.00	2.85	16.00
8. Excav., rock, wall ftgs.—410 cu.yd.	9.60	7.40	16.00
9. Excav., earth, borrow pits—77,000 cu.yd.	.73	.54	.75
10. Excav., rock, borrow pits—16,000 cu.yd.	.24	.85	.92
11. Backfill—1,000 cu.yd.	.96	.57	1.60
12. Earth fill embankment—67,000 cu.yd.	.25	.30	.25
13. Rock fill, downstream slope—13,000 cu.yd.	.65	.19	.25
14. Riprap, upstream slope—7,700 cu.yd.	.80	.34	1.00
15. Drill grout holes to 25 ft.—12,000 lin.ft.	.50	1.15	1.00
16. Drill grout holes, 25–50 ft.—12,000 lin.ft.	.80	1.00	2.00
17. Drill grout holes, 50–100 ft.—15,000 lin.ft.	1.10	1.30	2.00
18. Drill grout holes, 100–150 ft.—5,000 lin.ft.	1.25	1.70	2.00
19. Drill grout holes, 150–200 ft.—5,000 lin.ft.	1.25	2.30	2.00
20. Pressure grouting—210,000 cu.ft.	.94	.74	.65
21. Drill drainage holes to 25 ft.—1,000 lin.ft.	1.25	2.10	2.00
22. Drill drainage holes, 20–50 ft.—13,000 lin.ft.	1.60	2.30	2.00
23. Sewer pipe drains, gravel, 6 in.—190 lin.ft.	.50	.60	1.60
25. Sewer pipe drains, gravel, 12 in.—520 lin.ft.	.80	.85	1.60
26. Lay split sewer pipe, 24 in.—5,400 lin.ft.	.70	1.15	1.60
27. Lay split sewer pipe, 36 in.—780 lin.ft.	1.30	1.70	3.15
28. Porous concrete drain tile—31,000 lin.ft.	.67	1.43	1.00
29. Drill for anchor, grout bars—7,000 lin.ft.	.32	1.25	.55
30. Dam concrete—910,000 cu.yd.	3.10	4.15	5.50
31. Parapet concrete—180 cu.yd.	28.00	23.00	34.00
32. Spillway apron concrete—43,000 cu.yd.	7.00	4.50	8.50
33. Concrete, training wall below elev. 537—12,500 cu.yd.	6.35	7.05	6.70
34. Concrete, training wall above elev. 537—1,300 cu.yd.	10.00	10.45	9.00
35. Concrete, trash rack—1,220 cu.yd.	25.00	12.20	30.00
36. Concrete, embamkment cutoff—780 cu.yd.	10.00	13.85	18.00
37. Place reinforcing steel—5,300,000 lb.	.016	.0182	.02
38. Special concrete surface finish—700 sq.yd.	1.00	.90	1.50
39. Install metal sealing strips—25,000 lin.ft.	.24	.44	.30
40. Install tubing, fittings, for grouting joints—95,000 lb.	.21	.15	.16
41. Install trash rack metalwork—270,000 lb.	.016	.01	.02
42. Install paradox gates, operators—7,430,000 lb.	.03	.02	.015
43. Instal bulkheads, gates—440,000 lb.	.032	.024	.02
44. Bulkhead timber—35 M c.m.	70.00	75.00	80.00
45. Install penstock pipes—1,150,000 lb.	.021	.023	.02
46. Install metal stairs—6,000 lb.	.10	.03	.08
47. Install floor plates, gratings—12,000 lb.	.07	.035	.04
48. Install track rails—65,000 lb.	.03	.03	.03
49. Install metal pipe, fittings, valves—660,000 lb.	.054	.085	.08
50. Install pipe handrails—11,300 lb.	.08	.10	.16
51. Install elec. metal conduit to 1¼ in.—6,000 lin.ft.	.16	.40	.23
52. Install elec. metal conduit, 1¼ to 4 in.—3,500 lin.ft.	.32	.57	.40
53. Install elec. conductors—4,000 lb.	.08	.17	.30
54. Install elec. equipment—4,000 lb.	.24	.115	.40
55. Install ground wires—1,500 lb.	.05	.23	.30

Water and Sewer Lines, Massachusetts

CONSTRUCTION of 2 mi. of electric-welded, 48-in. steel pipe water line in Everett and Chelsea, and of 1¼ miles of 36 in. reinforced concrete sewer in Stoneham, Mass., is proceeding under two contracts awarded in September, 1936, by the Massachusetts Metropolitan District Commission. The following tabulation lists the quantities, unit prices and totals of the three low bidders on each part of the work. Alternative bids on lock-bar water pipe ran approximately 25 per cent higher than for electric welded.

I — Water Line, Everett and Chelsea.

(A) V. J. Grande Co., Boston, Mass. (contract)	$217,690
(B) A. G. Tomasello & Son, Inc., Boston, Mass.	221,659
(C) C. & R. Const. Co., Roslindale, Mass.	236,974

II — Relief Sewer Line, Stoneham.

(D) C. & R. Const. Co., Roslindale, Mass. (contract)	$159,578
(E) P. De Cristofaro Co., Inc., Roslindale, Mass.	166,734
(F) Edw. M. Matz Inc., Jamaica Plain, Mass.	167,033

I — WATER LINE, EVERETT AND CHELSEA, MASS.

Item	A	B	C
1. Elec. welded steel pipe, 48 in.—10,200 lin.ft.	$18.49	$18.35	20.00
2. Elec. welded steel pipe, 36 in.—25 lin.ft.	18.49	18.35	20.50
3. Lay only 12 in. c. i. pipe—130 lin.ft.	1.75	3.70	2.00
4. Lay only 6 in. c. i. pipe—110 lin.ft.	1.30	.75	1.50
5. Rock excav. above grade—50 cu.yd.	3.00	1.00	2.00
6. Rock excav. below grade—10 cu.yd.	3.00	5.00	5.00
7. Earth excav. below grade—500 cu.yd.	3.00	1.50	3.00
8. Chambers for 36 in. gate valves—4, each	160.00	250.00	100.00
9. Chambers for misc. valves—9, each	120.00	125.00	80.00
10. Chambers for air valves, manholes—21, each	50.00	75.00	50.00
11. Concrete masonry—980 cu.yd.	7.00	5.70	7.00
12. Spruce piles—1,000 lin.ft.	.35	.50	.50
13. Douglas fir timber—9 M.B.M.	100.00	50.00	50.00
14. Reset edgestone—750 lin.ft.	.20	.25	.50
15. Relay granite block pavement—3,100 sq.yd.	1.35	2.10	2.00
16. Bituminous macadam—4,300 sq.yd.	1.00	1.00	1.25
17. Reinforced concrete pavement—2,900 sq yd.	1.50	2.40	1.50
18. Relay brick pavement, conc. base—910 sq.yd.	1.40	2.25	2.00
19. Relay brick sidewalks—360 sq.yd.	.75	.75	.50
20. Granolithic Sidewalks—1,170 sq.yd.	1.00	1.80	1.80

II — RELIEF SEWER LINE, STONEHAM, MASS.

Item	D	E	F
1. Earth excav. timbered trench, relief sewer—25,000 cu.yd.	$1.40	$1.50	$1.80
2. Earth excav. timbered trench, pipes, drains—400 cu.yd.	1.00	1.50	2.20
3. Earth excav. backfill outside trenches—400 cu.yd.	1.00	1.75	3.00
4. Earth excav. backfill, untimbered tr.—2,000 cu.yd.	1.00	1.50	1.30
5. Earth excav. below grade—500 cu.yd.	1.00	3.00	1.00
6. Lumber, sheeting, used, removed—500 M.B.M.	2.00	5.00	5.00
7. Lumber, sheeting, left in place—500 M.B.M.	40.00	40.00	50.00
8. Steel sheet piles, used, removed—1,000 sq.ft.	.40	1.00	1.00
9. Steel sheet piles left in place—1,000 sq.ft.	.40	1.00	1.00
10. Rock excavation—1,000 cu.yd.	3.00	3.00	4.00
11. Pipe underdrains—6,900 lin.ft.	.20	1.50	1.00
12. Pumping, care stream, etc.—total	8,500	3,000	5,000
13. Gravel fill—1,000 cu.yd.	.40	1.50	1.25
14. Soil dressing, seeding—1,000 sq.yd.	.20	1.00	1.00
15. Concrete—500 cu.yd.	6.00	6.00	12.50
16. Concrete pipe cradles—300 cu.yd.	5.00	6.00	11.00
17. Reinforcing steel—1,000 lb.	.03	.05	.07
18. Brick masonry—180 cu.yd.	30.00	30.00	35.00
19. Grout pipes—20, each	.50	.50	2.00
20. Furnish grout—150 bags cmt	.60	.60	1.50
21. Grout operations—20, each	1.00	1.50	30.00
22. Pipes, sewers, drains—200 lin.ft.	1.00	2.00	3.00
23. C.I. pipes, sewer, drains, siphons—5 tons	40.00	75.00	40.00
24. Reinf. conc. pipe sewer, 36 in.—6,200 lin.ft.	11.50	10.00	6.50
25. Wood piles—1,000 lin.ft.	.10	.40	.50
26. Manhole frames, covers—16,000 lb.	.04	.075	.10
27. Misc. iron work—2,000 lb.	.05	.07	.10
28. Cold patch paving—300 sq.yd.	1.00	1.00	2.00
29. Granite—100 cu.ft.	1.00	2.00	5.00
30. Revetment paving—150 sq.yd.	1.00	1.50	3.00
31. Prepare site, cleaning, etc., total.	500.00	2,000	5,000
32. Bond—1½ per cent of total	2,358	2,464	2,468